Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6

MARCH 1953

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Consulting Engineers:
Messrs. McLellan and Partners

METALCLAD SWITCHGEAR AT ABBEY STEEL WORKS

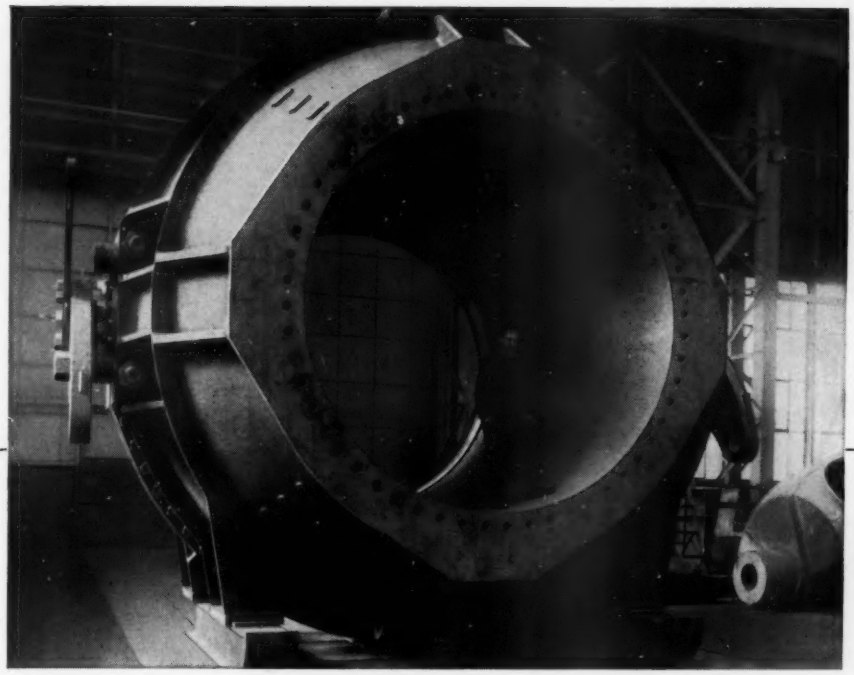
Reyrolle Metalclad horizontal draw-out switchgear was selected for the main control of supplies within the Abbey Steel Works, Port Talbot, South Wales. The 11 kV switchboards are of various ratings, these being type B5T with oil-break circuit-breakers of 500 MVA breaking capacity and types B3T and B2T switchgear of 350 MVA and 250 MVA breaking capacity respectively.

If you want to talk switchgear ... talk to Reyrolle

A. Reyrolle & Company Ltd., Hebburn, Co. Durham.

CEC 198

160 ton Straightflow Valve



'ENGLISH ELECTRIC' have recently delivered three 11 ft. bore straightflow valves—probably the largest smooth-bore valves in the world—and are making two more. These valves work under a head of 322 ft. and the overall diameter is 20 ft. Operation is by external servo-motors. Each valve serves as an inlet valve for a 74,000 h.p. 'ENGLISH ELECTRIC' water turbine.

'ENGLISH ELECTRIC' straightflow valves are manufactured for all diameters and heads, and their robust spherical form makes them particularly suitable for high pressures. Their principle of operation eliminates water-hammer, wear and backlash, side thrust and vibration. They are positive and safe; no deviation of water stream can take place when they are being opened or closed.

'ENGLISH ELECTRIC'

water power

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Hydro-electric Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

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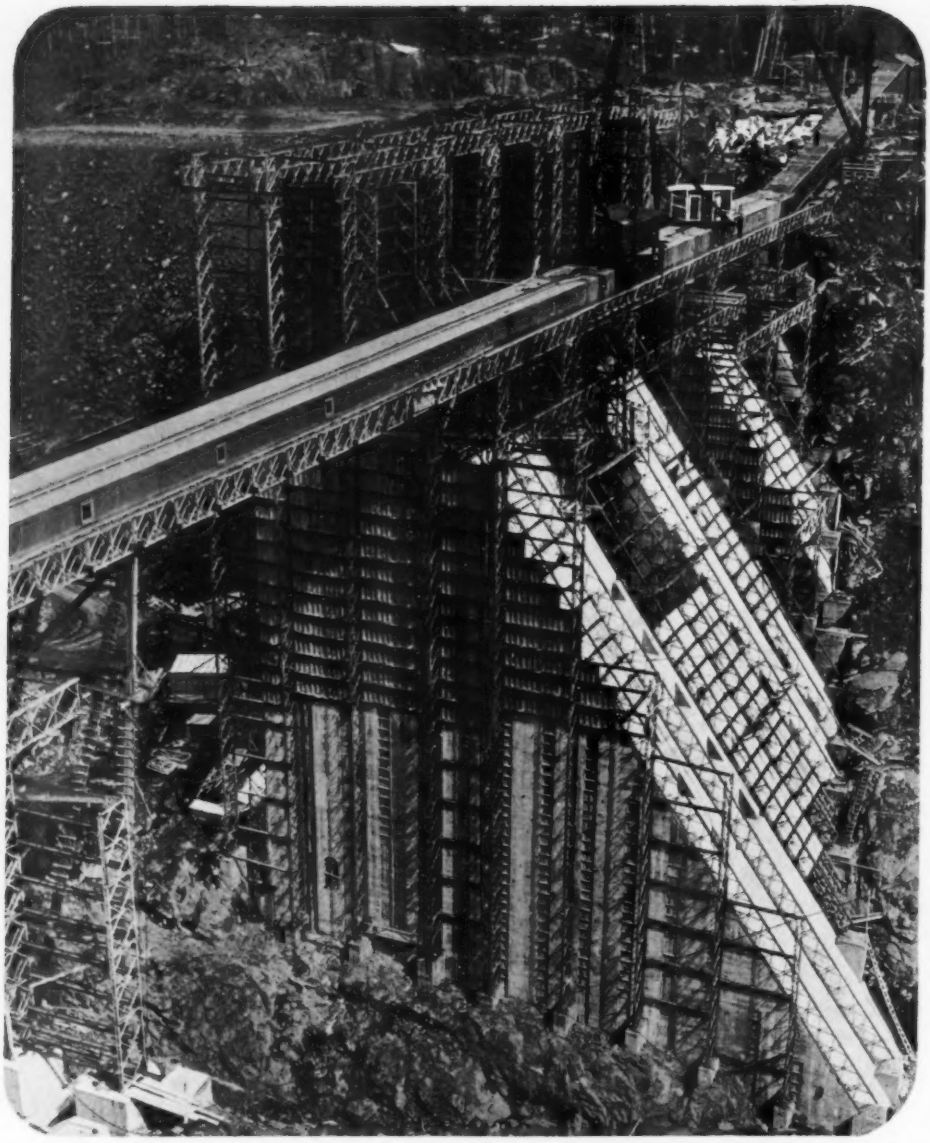

Photograph by courtesy of the Ontario Hydro Electric Commission

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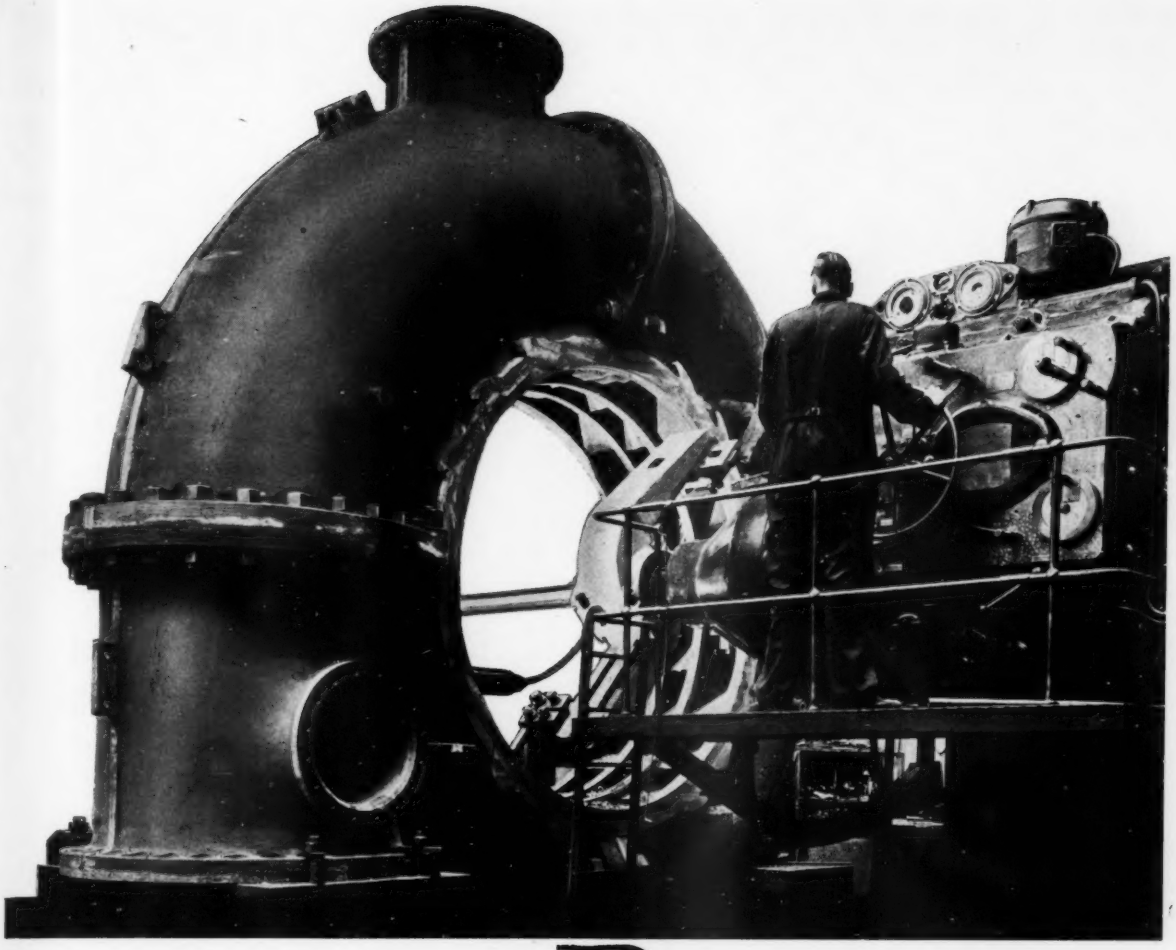

Boving

TURBINES FOR TUNGATINAH TASMANIA

The illustrations show machining in progress on one of the cast steel spiral casings and a completed relief valve. Five turbines with rotary type inlet valves and automatic relief valves are being supplied to the Hydro-Electric Commission of Tasmania for Tungatinah.

Each unit is rated at 35,000 H.P., 600 r.p.m., 950 ft. net head

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MELBOURNE OFFICE: 99 QUEEN STREET

WATER TURBINES — PULP AND PAPER MACHINERY

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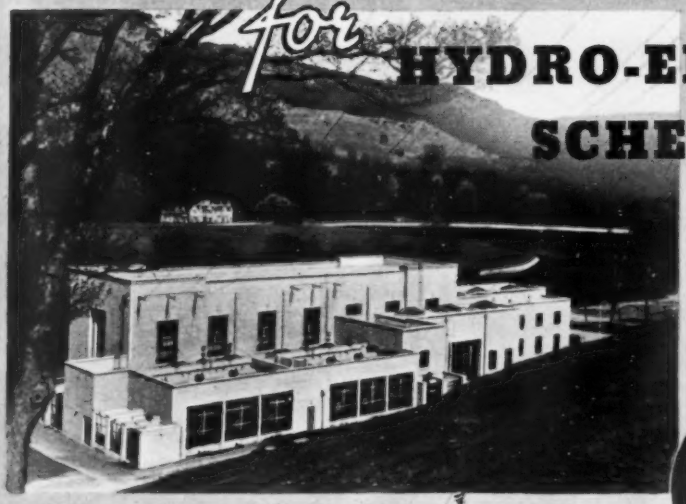
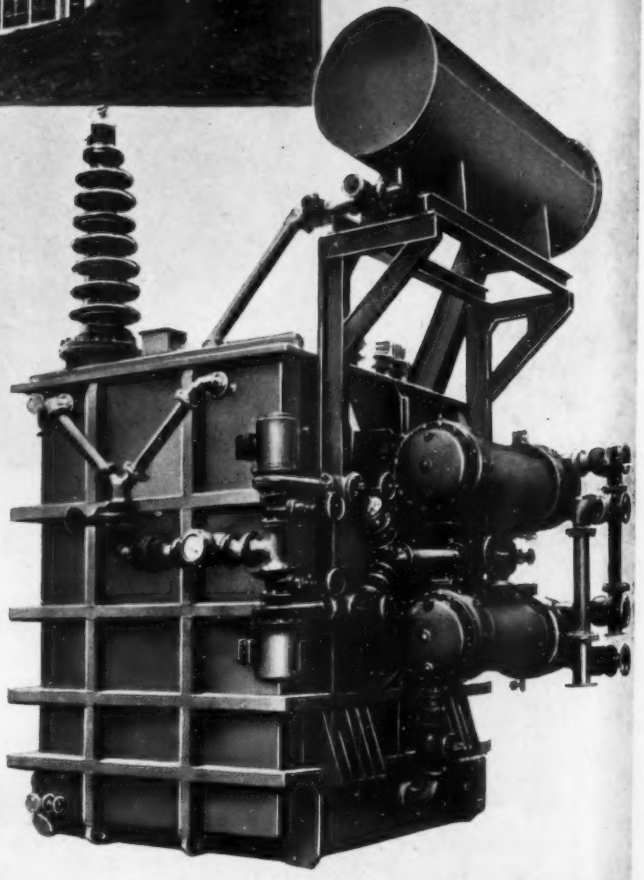
PEEBLES

power transformers

for HYDRO-ELECTRIC SCHEMES



CLUNIE POWER STATION of the North of Scotland Hydro-Electric Board where 6-20,000 K.V.A. water-cooled transformers, as illustrated at right, operate in two 60,000 K.V.A. 11,000/132,000-volt three-phase banks. Also installed at this power station is a three-phase magnetically shielded reactor capable of dealing with a power fault of 400,000 K.V.A. at 11,000 volts.



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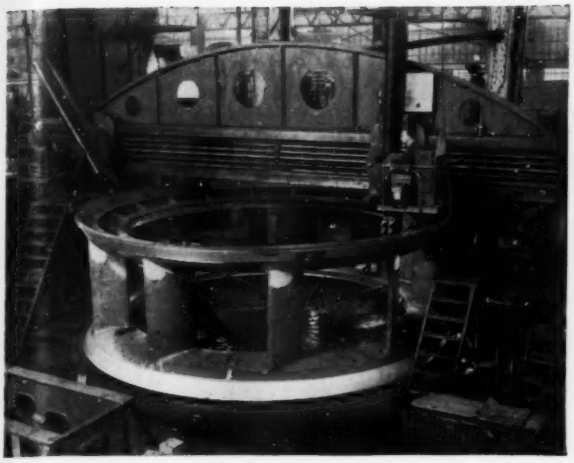

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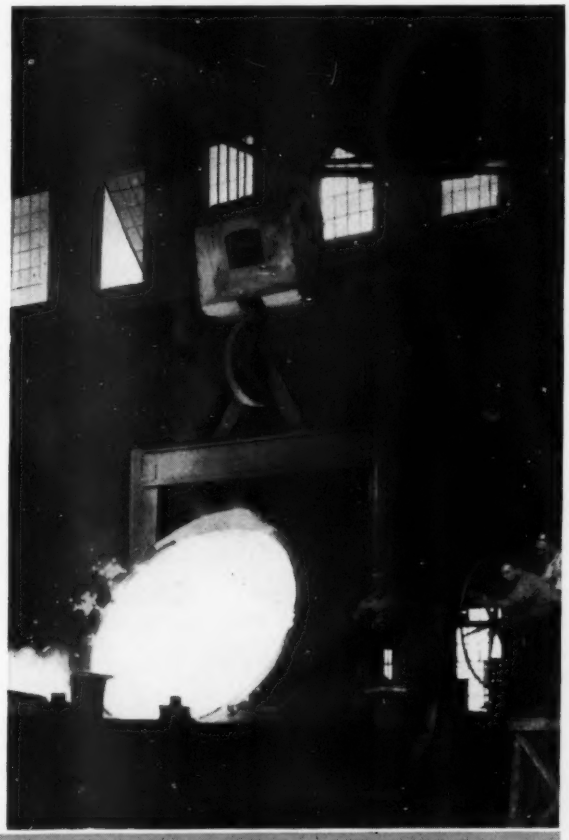
Francis, Propeller or Impulse—small, medium or large—at Dominion Engineering are the complete facilities and the long, specialized experience to produce them.

Here, for example, are foundries which produce iron, steel and bronze castings. Here, too, are plate steel and machine shops equipped with a complete variety of tools to fabricate any size or type of turbine.

The extent of such facilities is your assurance of quality production and good deliveries to any part of the world. Dominion Engineering is at your service whenever you are considering new water power developments.

Write to P.O. Box 220, Montreal, for Hydraulic Turbines Bulletin No. 201.



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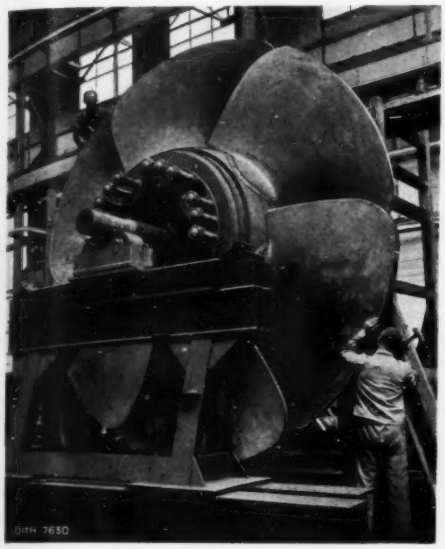


Illustrations:

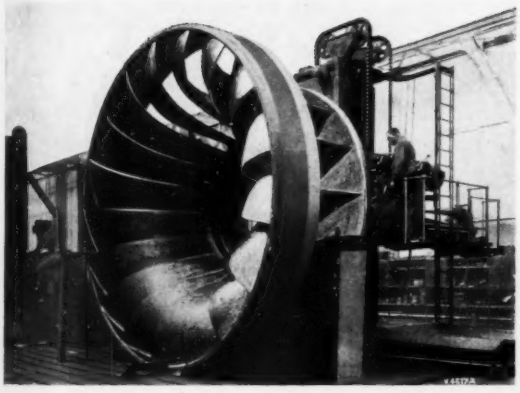
On the left: 34,600 H.P., Hirakud II (India)

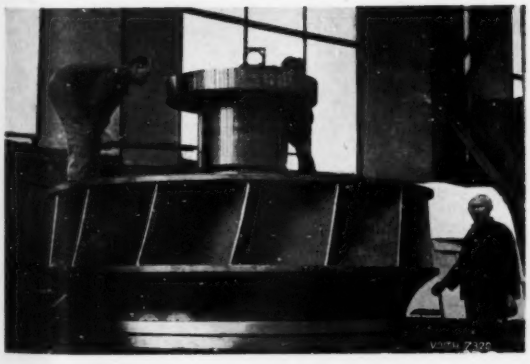
Below: Runner 15 feet diameter, 115,500 H.P., Sungari (Manchuria)

On the right: 52,400 H.P., Cipreses (Chile)

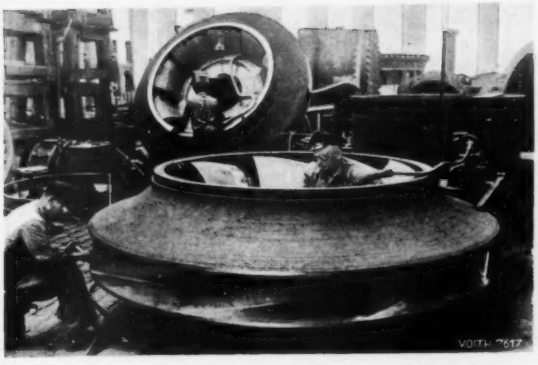
Below: Split runner 16′ 5″ diameter, 60,000 H.P., Parahyba (Brazil)

In the foreground: the runner model





Runner 60,000 H.P. output, Waldshut (Germany)



Storage Pump Impeller 24,100 H.P. input, Waldshut

J.M. Voith G.m.b.H., Engineering Works, Heidenheim (Brenz)

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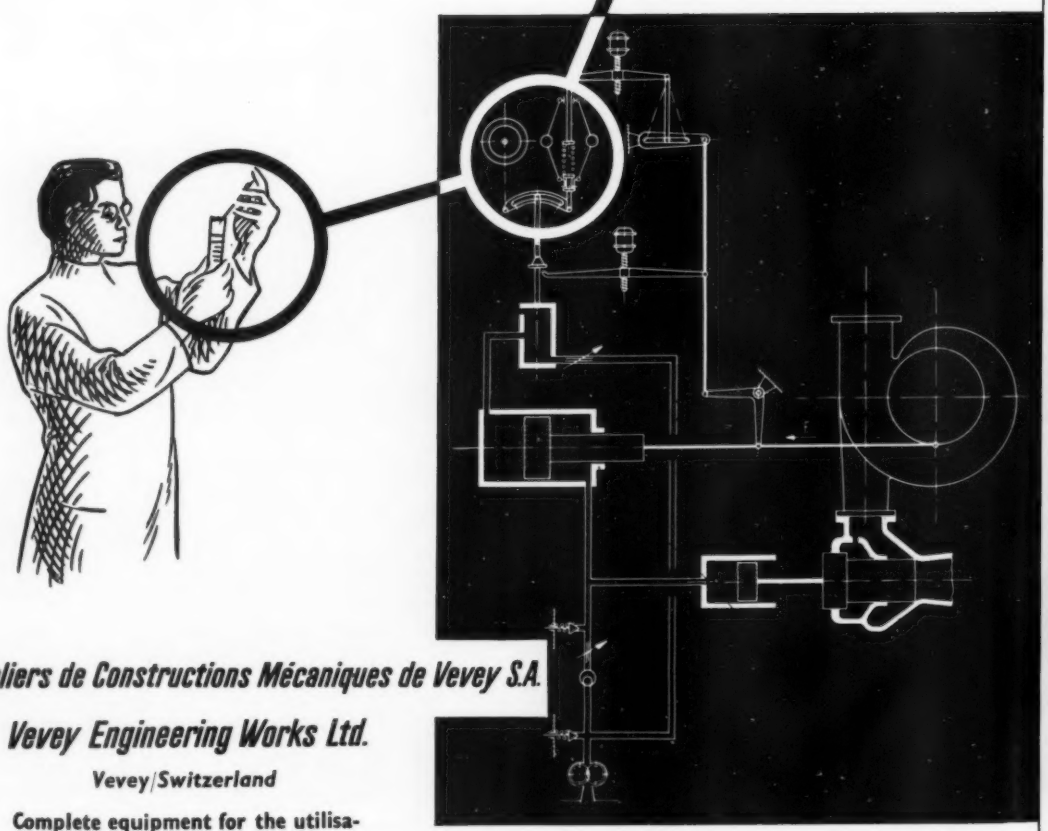
is the only one allowing exact control of the effects of the accelerometer and tachometer during operation. This particular quality makes the VEVEY governor a modern apparatus insuring great sensitiveness in speed regulation combined with improved running stability.



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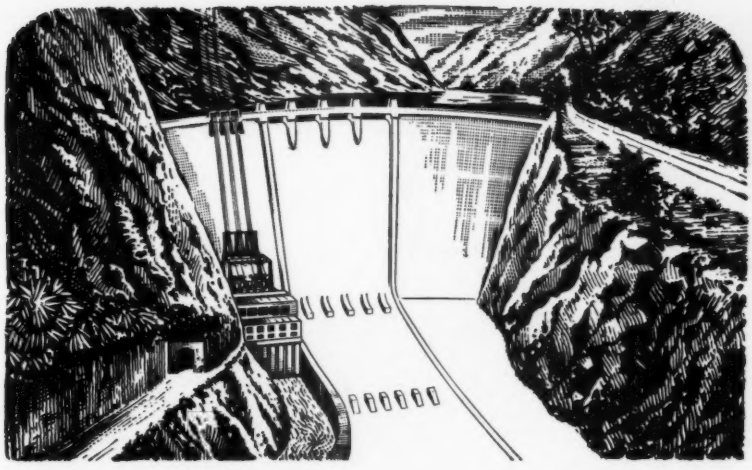
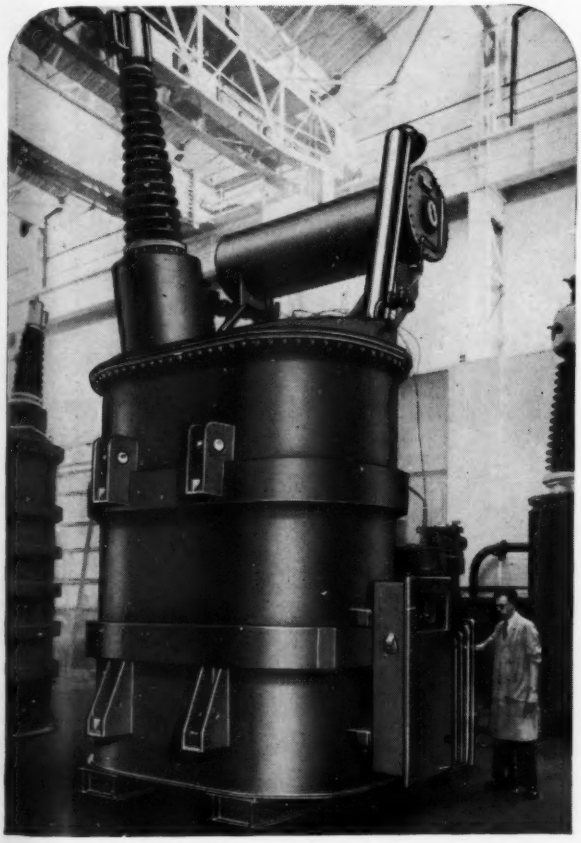


Hydro-electric Equipment



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Top: Artist's impression of the Los Peares Power Station, North West Spain.

Left: One of the ten 20,500-kVA., single-phase, 50-cycle, Type OFW Transformers (on test in BTH works) forming three 61,500-kVA., 11/132-kV. three-phase banks, plus one spare unit, for the above Power Station.

For all plant required for Hydro-electric Power Schemes — **Consult BTH.**

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Head : 590 mt.
Output : 102,000 h.p.
Speed : 428 r.p.m.

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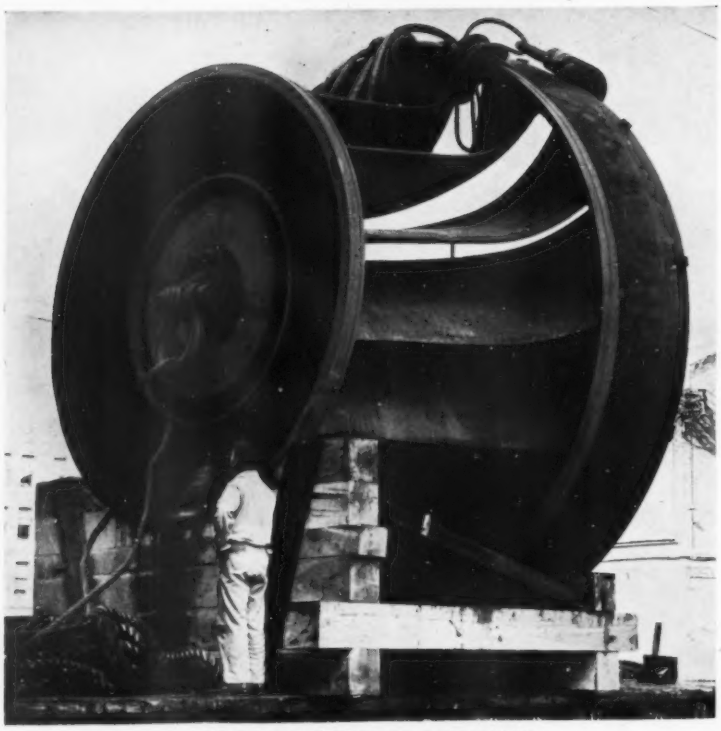
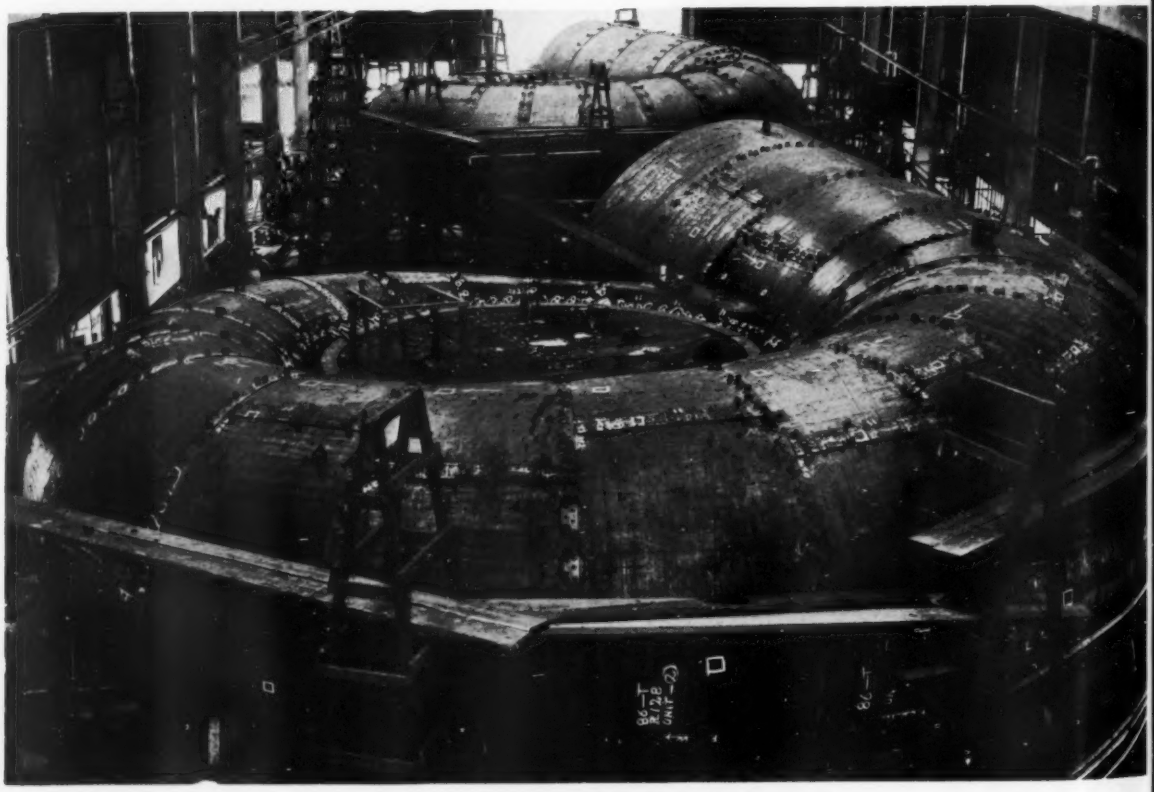


RUNNER FOR BUGGS ISLAND DEVELOPMENT

OVER EIGHT MILLION HORSEPOWER

The Newport News Shipbuilding and Dry Dock Company has received orders for the building of hydraulic turbines aggregate rated output of 8,135,000 horsepower.



ASSEMBLY OF SPIRAL CASINGS FOR C. J. STRIKE DEVELOPMENT

NEWPORT NEWS
SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia

Metering and Control . . .

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Control room at La Dernier hydro-electric power station of the Compagnie vaudoise des forces motrices des lacs de Joux et de l'Orbe, Lausanne, Switzerland.

All changes in operating conditions, e.g., position of circuit-breakers, are confirmed on the dummy board which is arranged with relay and control panels on either side of it.

CONTROL ROOMS

with or without luminous diagrams for electricity supply and industrial plants meet all possible requirements and facilitate the duties of the operator.

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SHREWD City Officials and City, Consulting and Sanitary Engineers, and Plant Superintendents having charge of enormous river areas and Public-service Systems, after rigid examination, have adopted Smith Pumps.

This acceptance is due to the Smith Pump design —a decided improvement over the pumps previously used, because its automatically-adjustable vane impellers greatly improve performance for low heads; high volume requirements met in flood control, irrigation, sanitation and industrial projects!

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3 WINDINGS : 150/70/10 kV.
ON LOAD VOLTAGE REGULATION : ± 17,5 % ON THE 150 kV SIDE
3 RANGES OF LOAD ; 45 000 kVA - 60 000 kVA - 75 000 kVA according to the type of cooling system.

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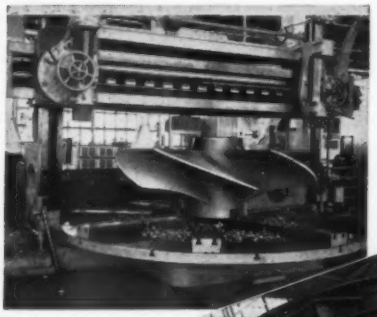
HYDRAULIC TURBINE

increases

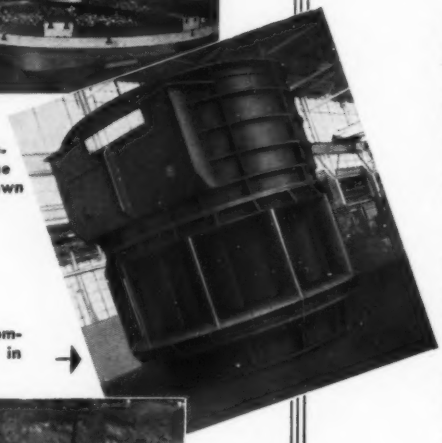
power output at

WILBUR DAM

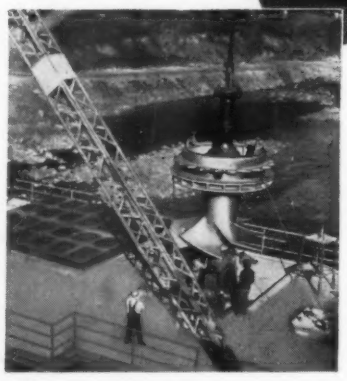
of the Tennessee Valley Authority



Cast steel propeller-type runner for the Wilbur turbine, shown on boring mill.



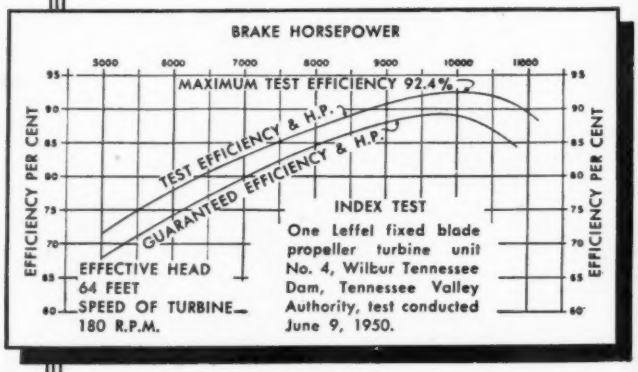
Wilbur turbine, completely assembled in the Leffel plant.



Lifting the combined runner, shaft and coverplate during the field installation.

The Wilbur power project of the TVA is another instance where a Leffel hydraulic turbine was used for the expansion of existing power facilities. For the Wilbur installation a Leffel vertical propeller-type hydraulic turbine was used — maximum rated at 11,500 HP, under 67 feet net head, speed 180 RPM.

The Wilbur project demonstrates once again that the long-range economy and dependability of Leffel turbines make a valuable asset for any expansion or rehabilitation. Our facilities are backed by 91 years of reliable service to the water power industry. Why not let us help you with your project, whether it be expansion, rehabilitation or a new installation?



Field Test Results

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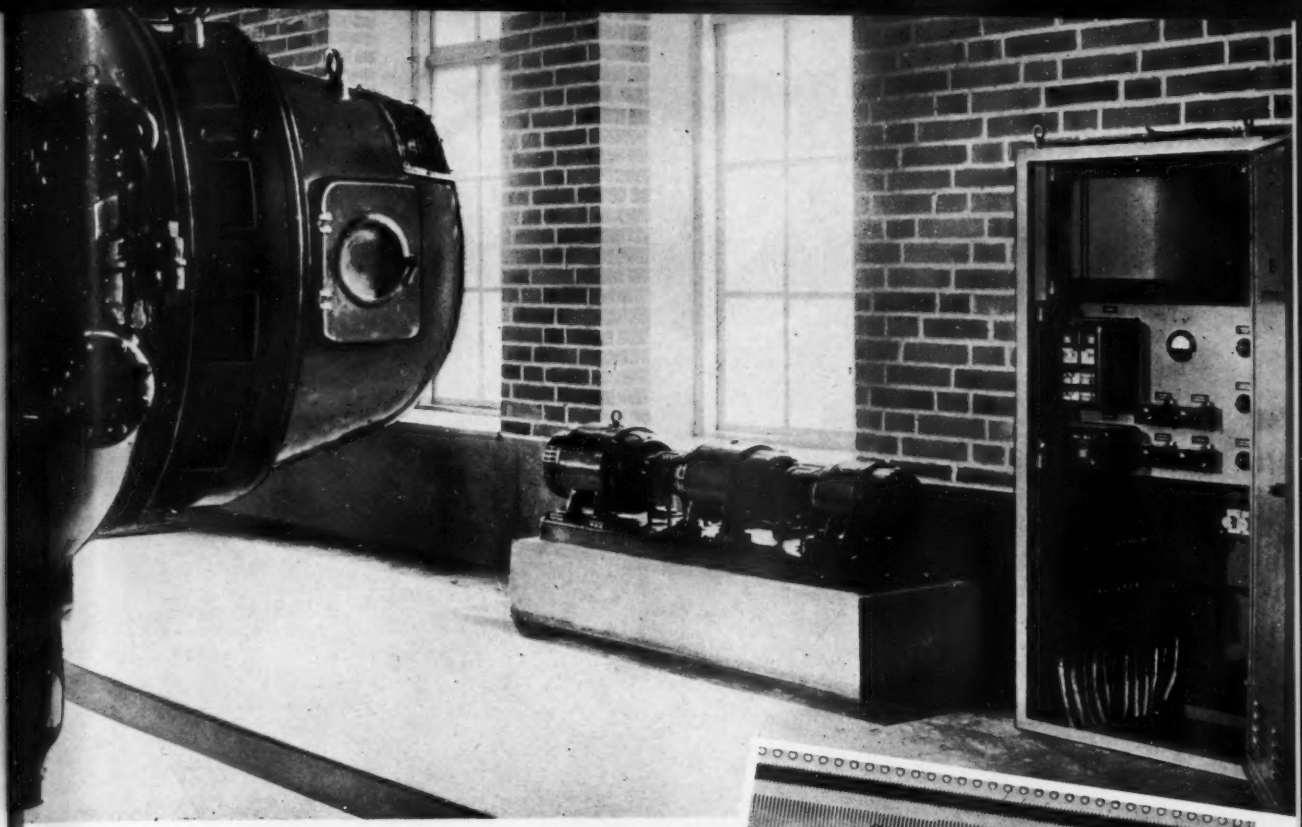
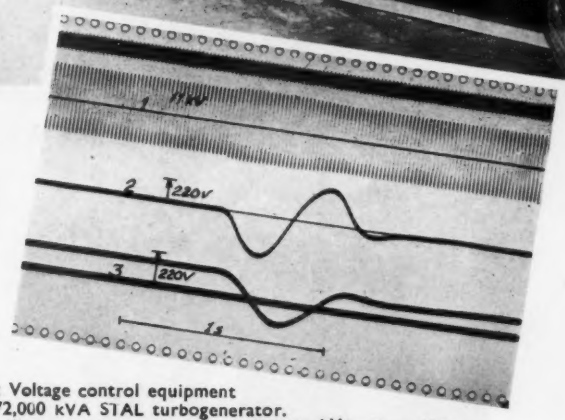
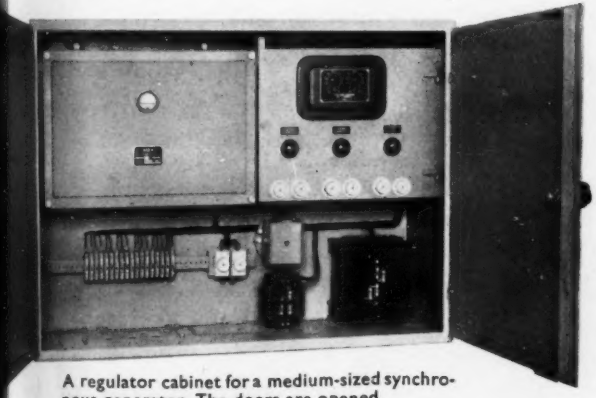


oltage control

for synchronous machines



Above: Voltage control equipment
for a 72,000 kVA STAL turbogenerator.
The oscillogram shows switching out 30,000 kVAr, $\varphi = +90°$.
1. Generator voltage. 2. Booster exciter voltage. 3. Exciter voltage.



A regulator cabinet for a medium-sized synchronous generator. The doors are opened.

The ASEA system of high speed voltage control, originally patented in 1925, has been a subject of intensive research and development, culminating in the modern transductor regulator, which embodies all the above-mentioned features. It is of unique design, providing continuous voltage control, and requiring no maintenance whatsoever. It is devoid of contacts or any other moving parts, containing only components which have a practically unlimited life. In theory it is possible to shorten the time taken for voltage regulation indefinitely, provided that the exciter equipment is appropriately designed, whereas in practice it is a question compromising between performance and economy. The ASEA high speed regulator improves the service reliability of the power plant and increases the transmission capacity of the line. In the event of short circuits or rapid load fluctuations, the excitation can rapidly be adjusted so as to increase the synchronizing torque and thus minimise the risk of hunting or dropping out of synchronism. The power line can be utilised more effectively as the regulator enables the system to be run closer to the stability limit without jeopardising the reliability of the system.

The first transductor regulator and booster exciter set were put into service in 1945. Transductor regulators manufactured since then represent an aggregate control capacity of 4,000,000 kVA or in course of manufacture, for machines up to a size of 105,000 kVA. Experience with these regulators in service has been very good. Transductor type regulators without booster exciters for small generators can be supplied within short delivery time.

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Runner for *one of the three* KMW Turbine Units of the Kilforsen Power Plant, owned by the Royal Swedish Board of Waterfalls.

Output: 121,350 H.P.
Head: 327 feet.
Speed: 166.7 r.p.m.
Water Quantity: 3615 cusecs.

The stainless steel runners are solid cast by Domnarfvet Steel Works, Sweden, and finished at KMW's works at Kristinehamn. They have a net weight of 35 tons each.

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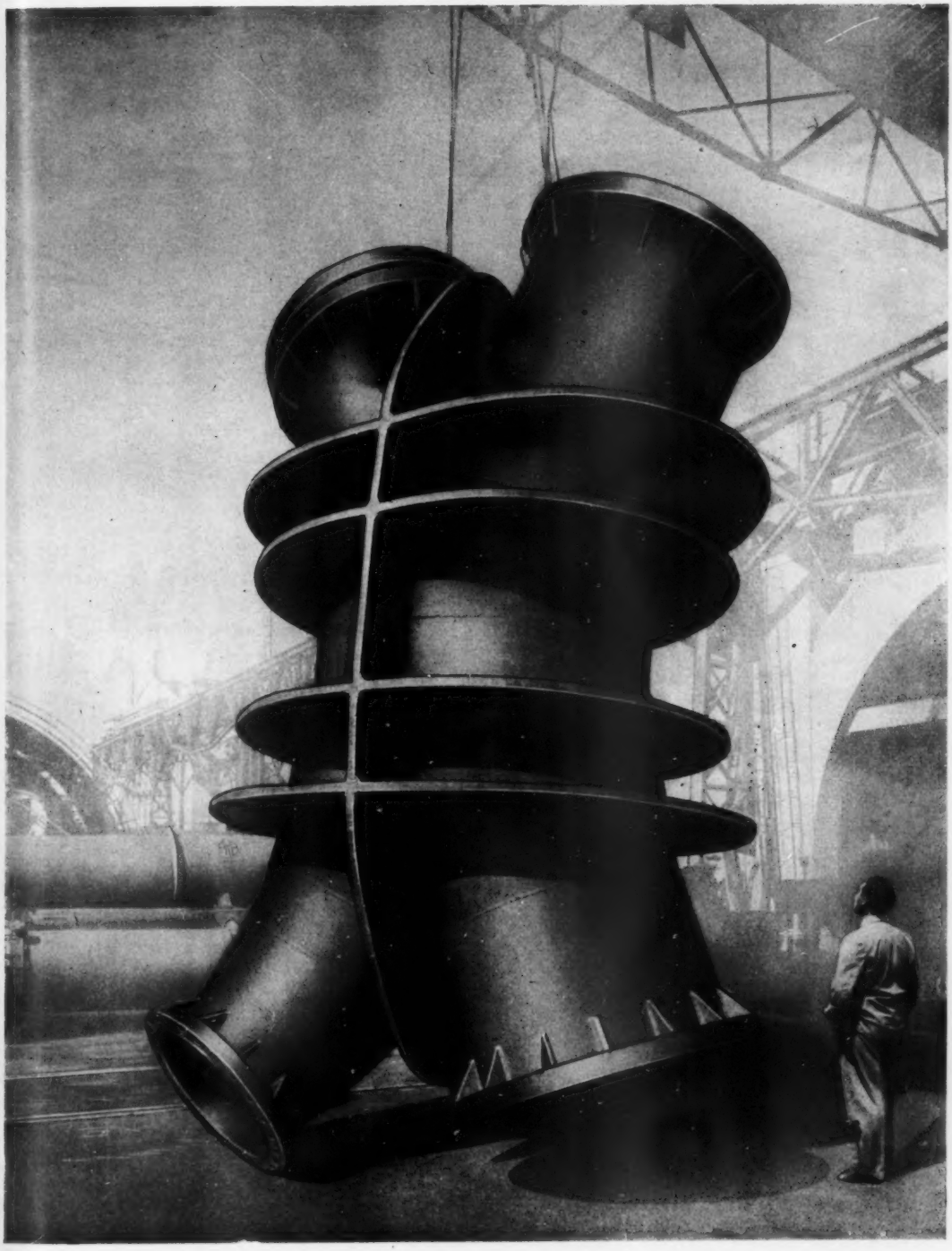

Four-forked piece made of welded steel plate for the "Volturno" Hydro-Electric Plant, Italy

ACCIAIERIA E TUBIFICIO DI BRESCIA BRESCIA (ITALY)

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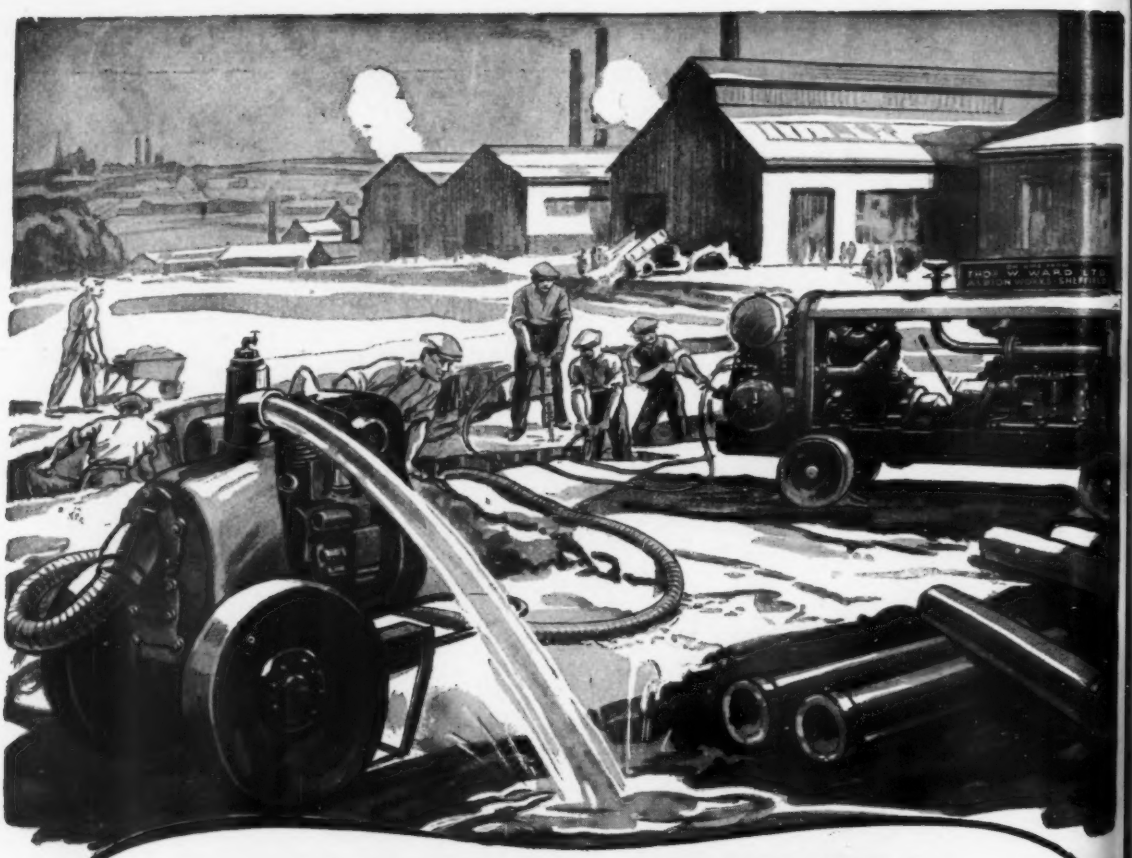

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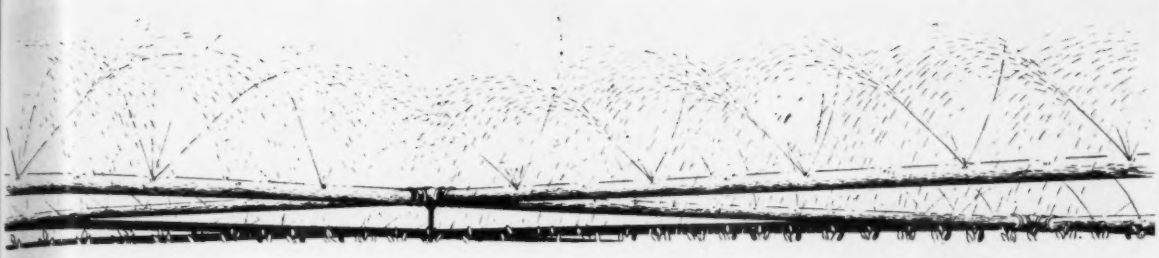

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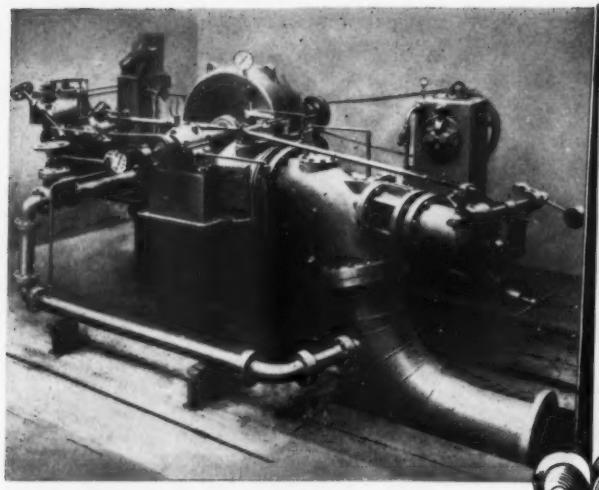
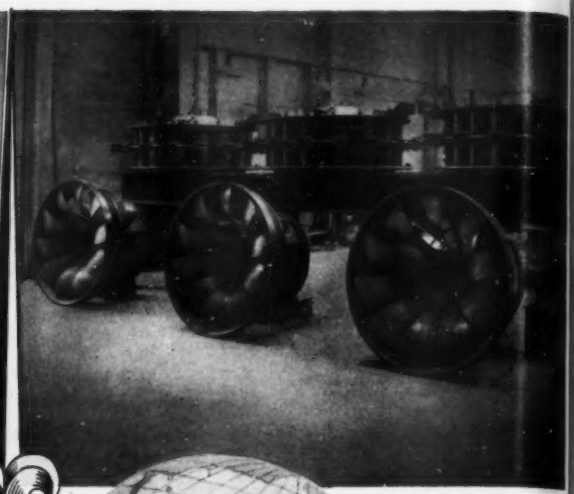


ICELAND—1200 H P Turgo Impulse Wheel for the River Fossa Development of the State Electricity Authority.



TIBET—Three 204 H.P. Open Penstock Francis Turbines for the Lhasa Hydro-Electric scheme.

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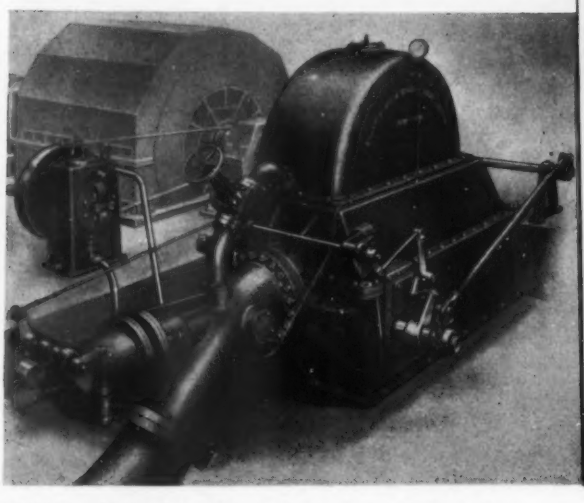

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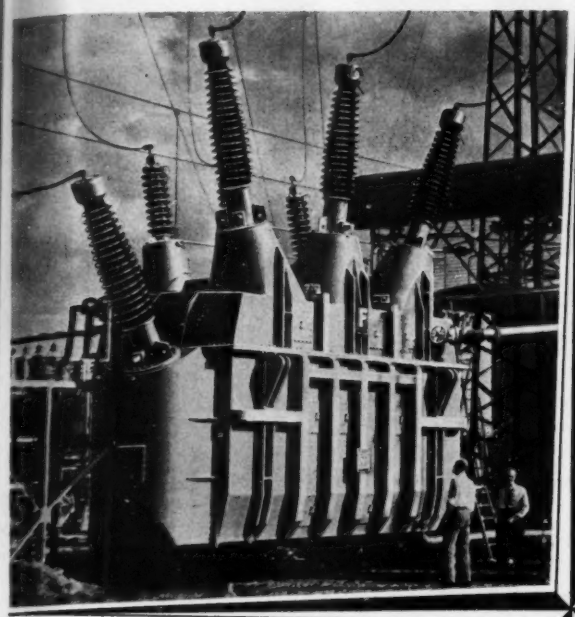

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Opposite: One of the completed transformers in commission at the Pyhäkoski Generating Station.

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Through Ferranti Electric Inc., New York, the Ferranti organisation has secured in open competition the contract to supply the U.S. Army Corps of Engineers with nine single-phase 13.2/230 kV, 33,333 kVA generator transformers, forming three 3-phase 100,000 kVA banks, each bank connected to the 13.8 kV output of one 80,000 kVA hydroelectric generator with a maximum continuous rating of 97,800 kVA.

CANADA

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Ferranti transformers ordered for this project comprise four 71,000 kVA single-phase generator transformers forming a 213,000 kVA, 13,200/301,000 volt 3-phase bank at KEMANO and three 37,000 kVA, single-phase step-down transformers at KITIMAT, will form a 111,000 kVA, 275,000/13,200 volt 3-phase bank. The contract was secured against international competition by the Ferranti Electric Ltd., Toronto, Canada.

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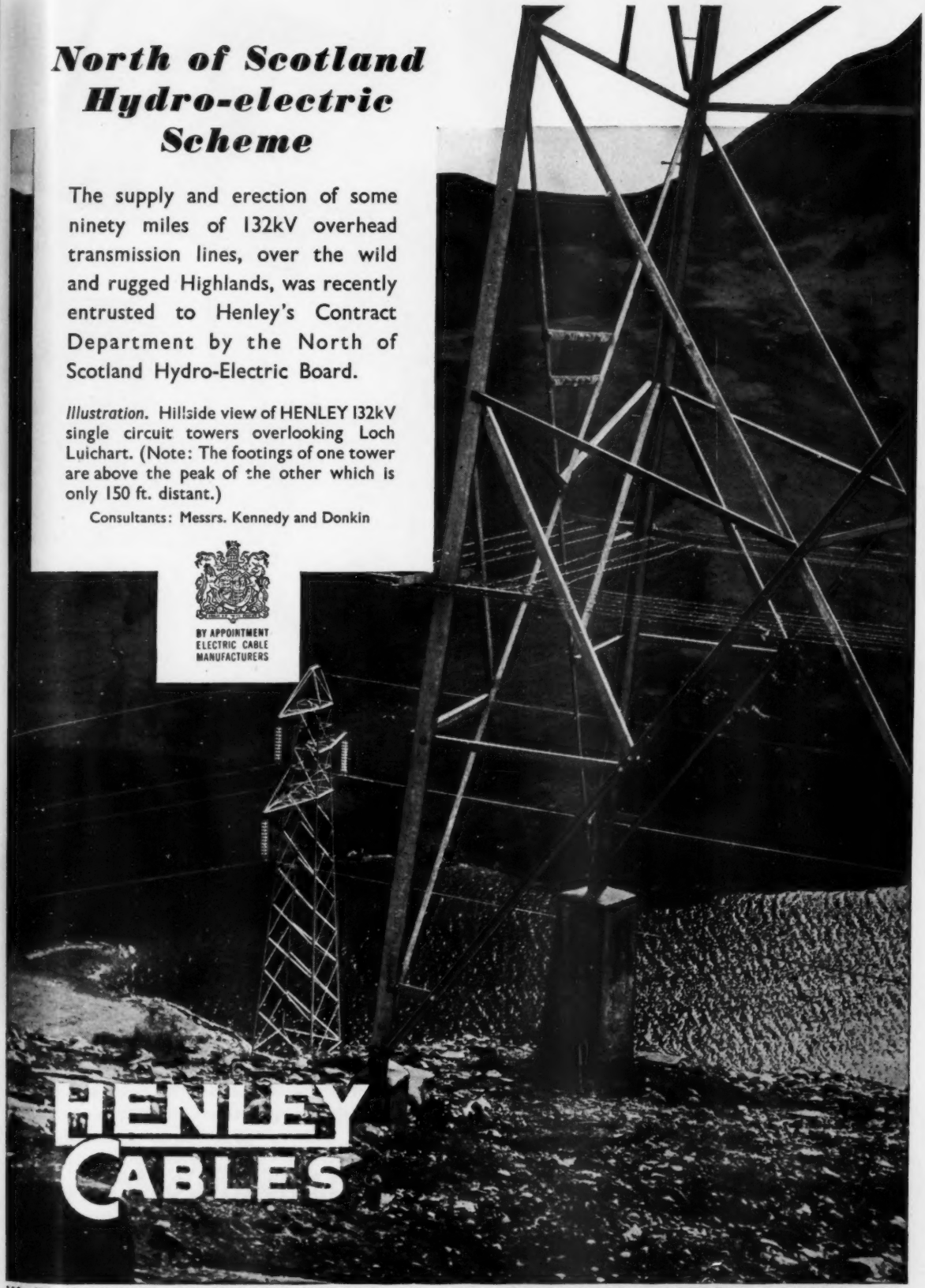

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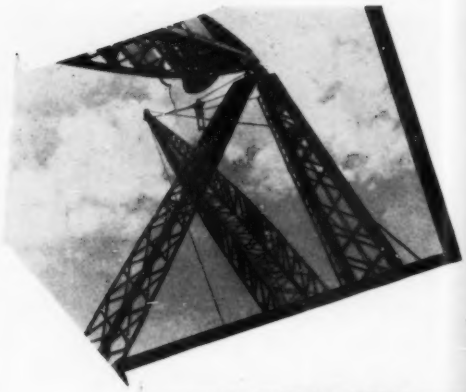

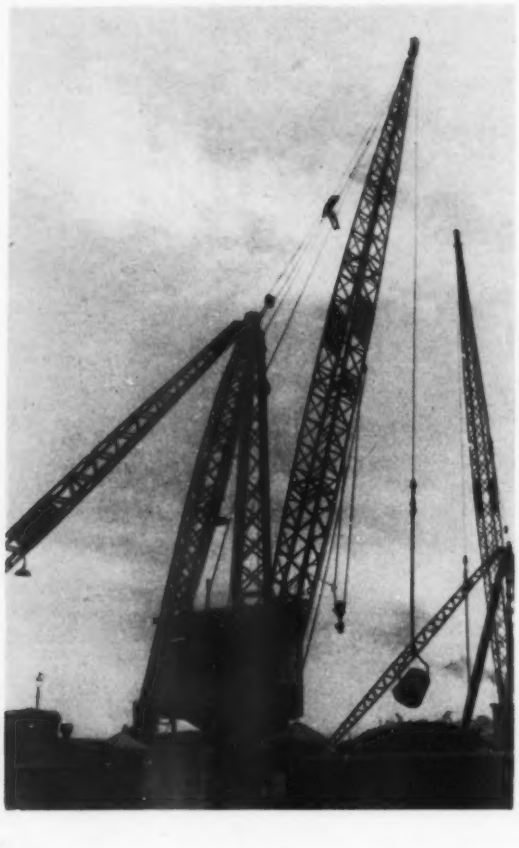

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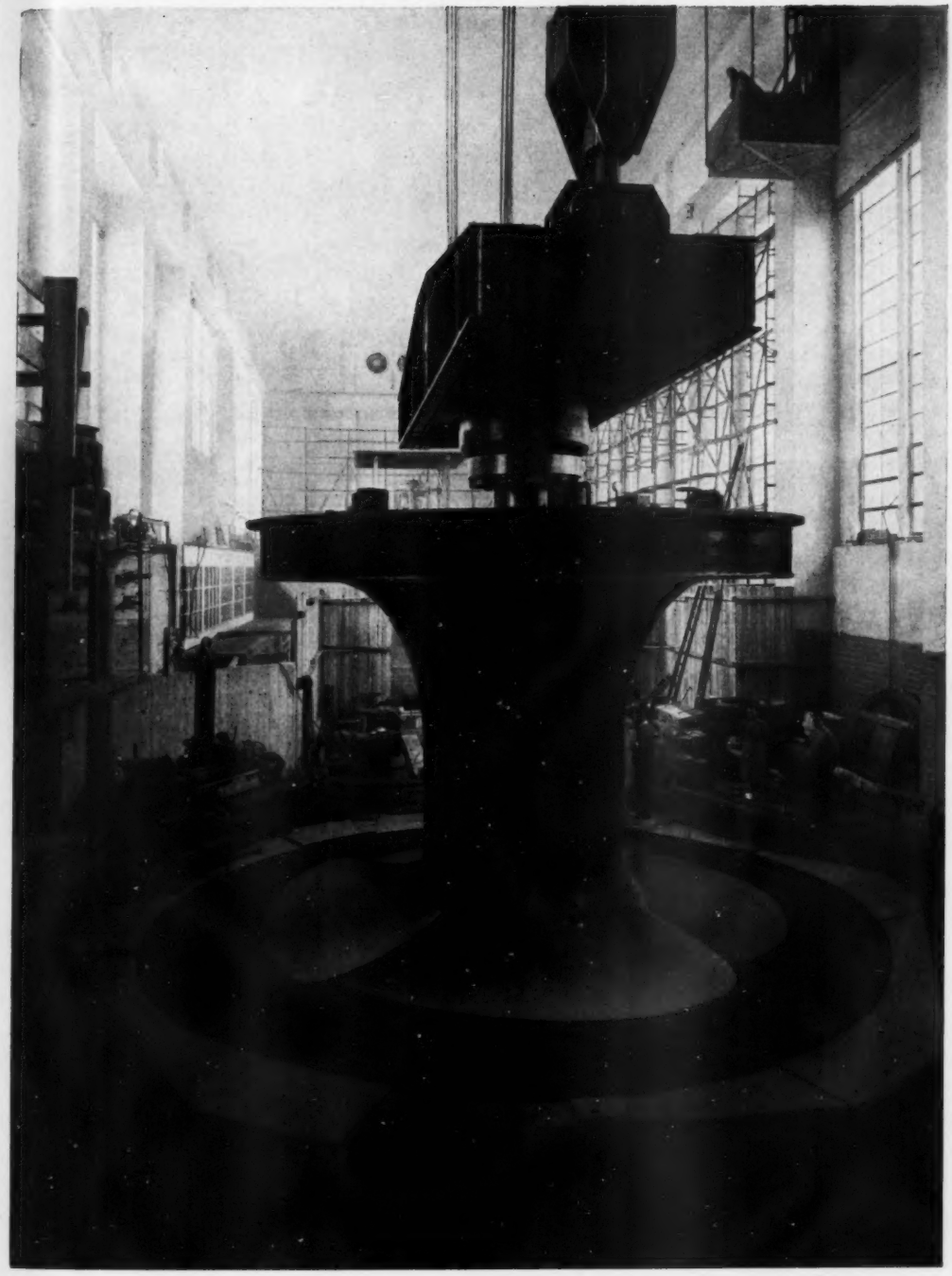

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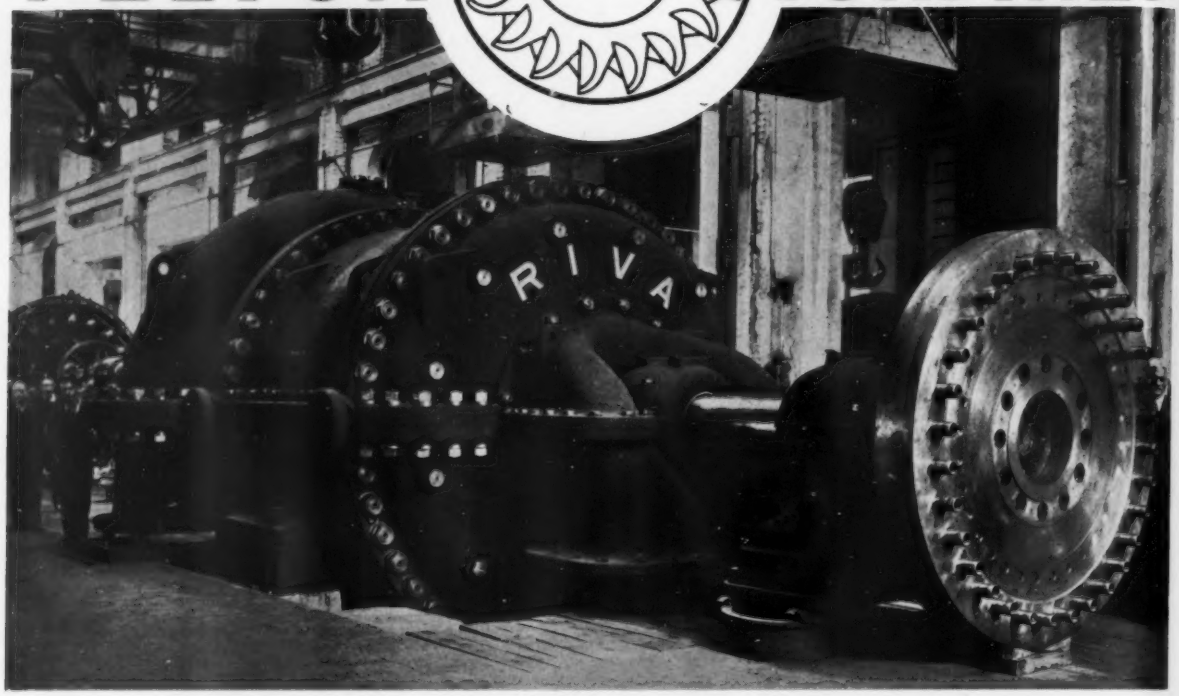

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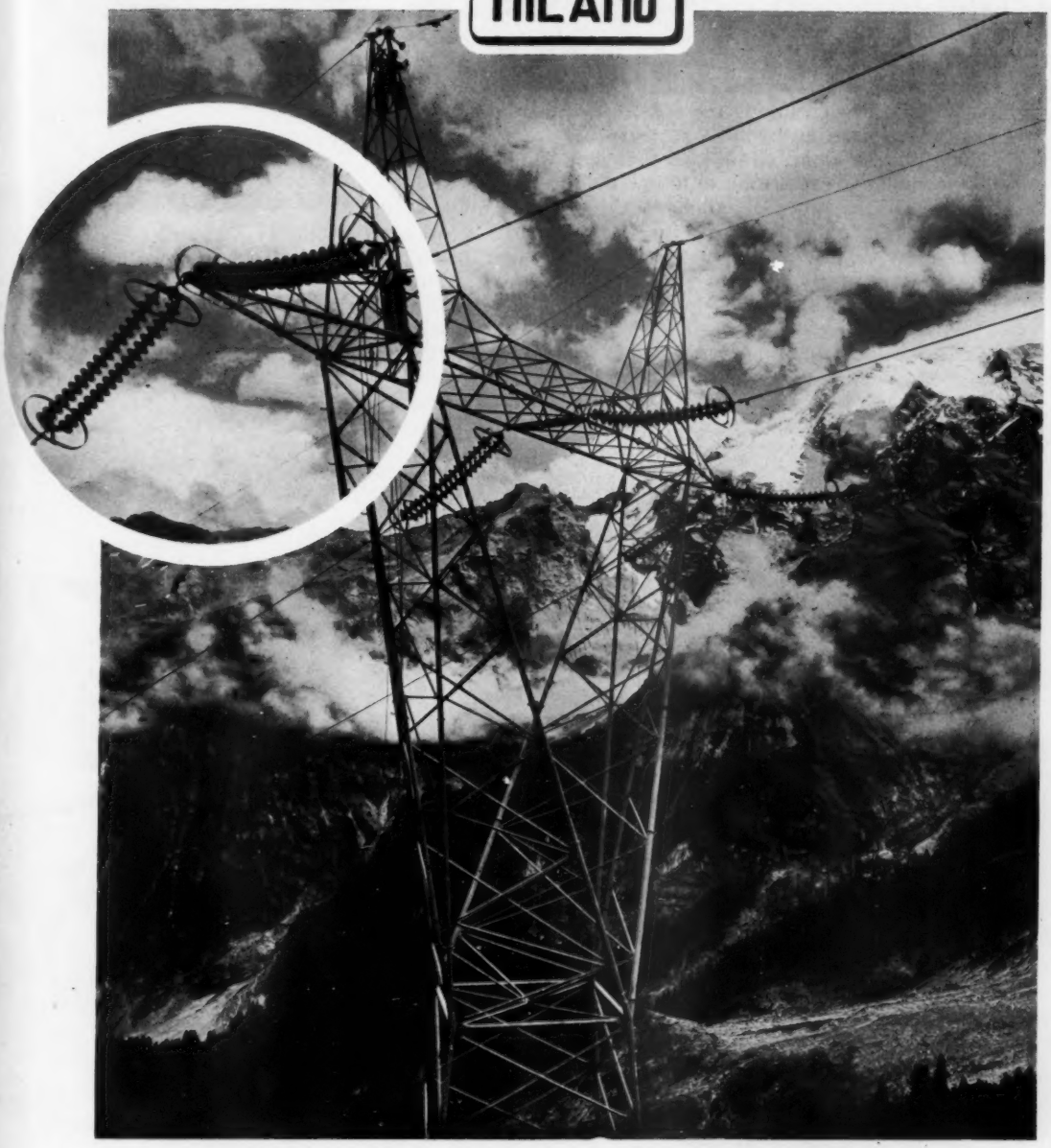

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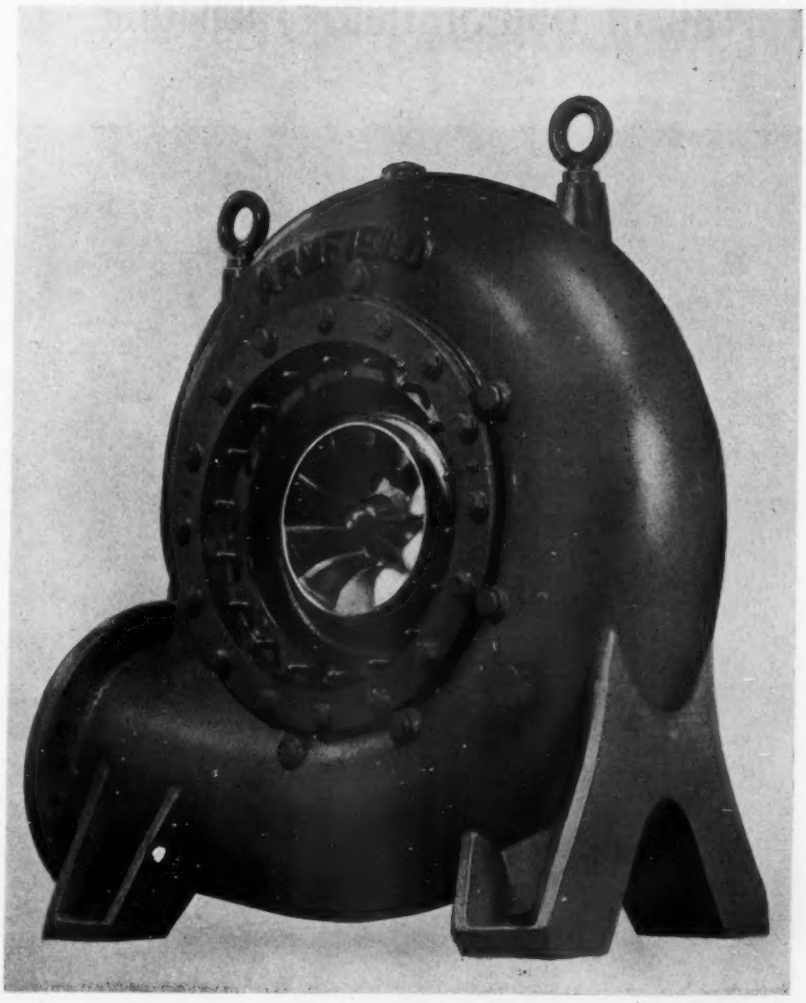
The illustration is of a horizontal shaft cased Francis Turbine for operation under a head of 90 ft. This machine has recently been built for electric power generation at a Tea Factory in Ceylon.



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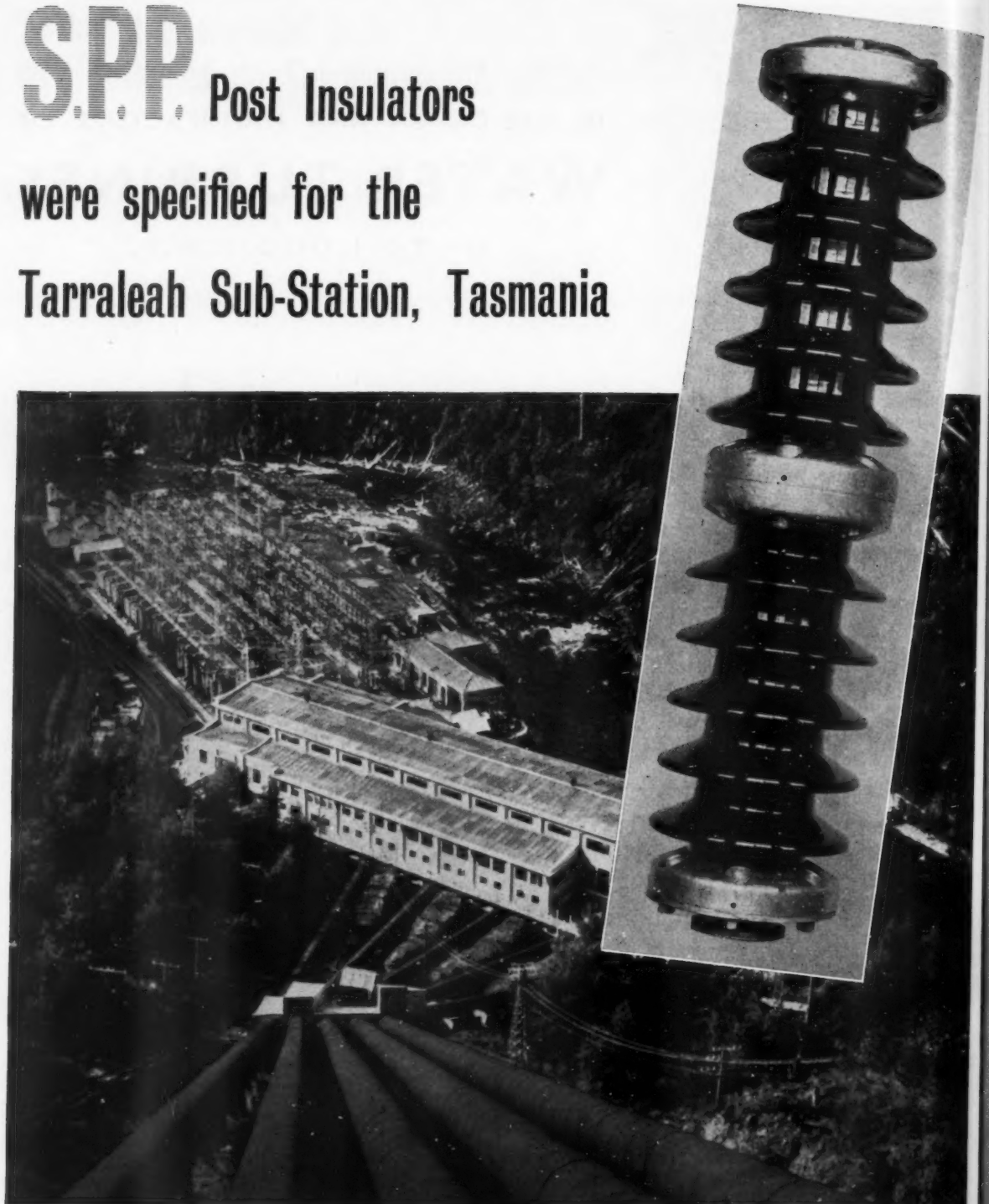

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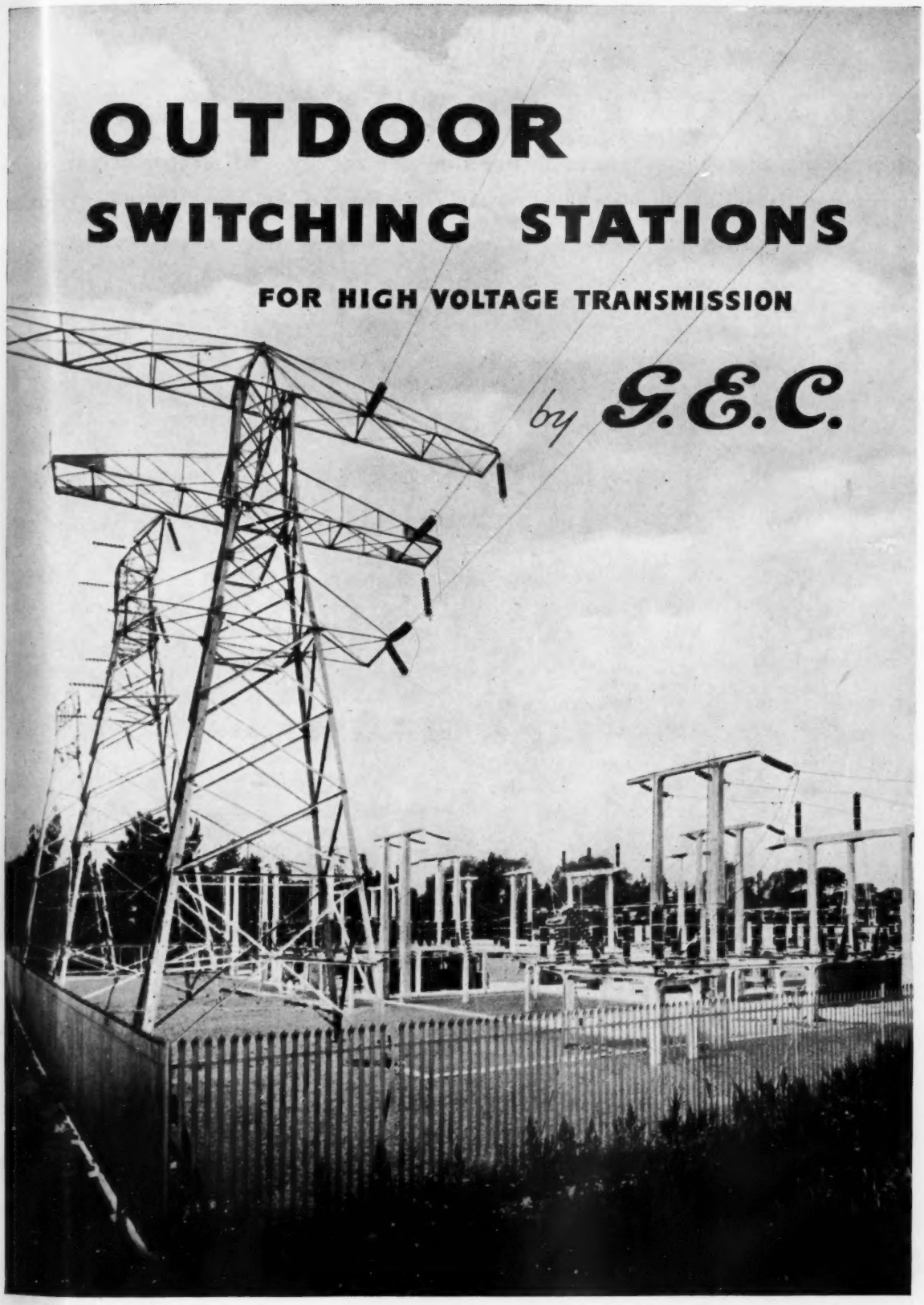

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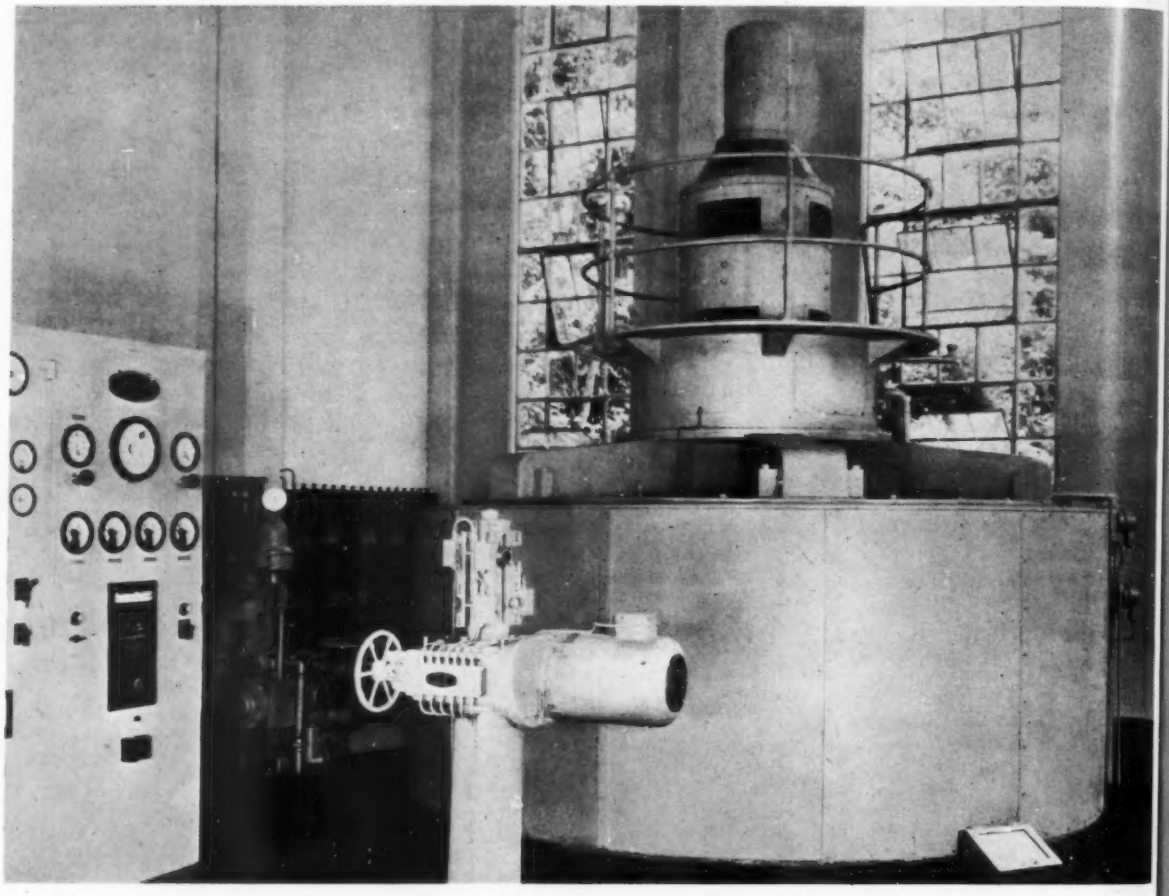

General view of alternator, turbine panel, governor and "Rotovalve" control pedestal

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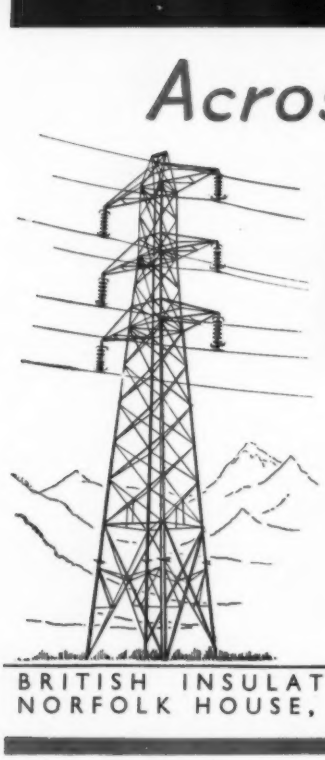

BICC OVERHEAD TRANSMISSION

It's a tough job erecting lines and towers across the mountains, valleys and jungles of Ceylon. But BICC Engineers are used to work of this nature : they have recently completed the overhead transmission system for the first stage of the Laksapana Hydro-Electric Scheme. This comprises seventy-eight miles of double-circuit 66kV line to carry 25,000 kW of power to Colombo and Peradeniya.

Survey, siting, supply and erection of this transmission system were all carried out by the BICC group—who undertake similar installations anywhere in the World.

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The Kafue Report

THE logical development of water power in the Rhodesias has been brought a step nearer by the publication of the report on the Kafue Gorge scheme, which was formally presented to the Northern Rhodesian Government on January 29. This report forms the sequel to that presented in December 1950 to the Governments of both Northern and Southern Rhodesia on Kariba Gorge,* and has been prepared by the same panel of consulting engineers — Sir William Halcrow, Mr. Harold Gourley, Mr. C. H. Pickworth and Mr. Geoffrey Kennedy.

The Kariba report recommended a scheme giving an ultimate output of 1,000 MW at 70 per cent. load factor, to be constructed in stages, the first consisting of four 77 MW sets out of a total of 14. It would be necessary, however, to construct the dam at once to its full height, and the initial scheme was estimated to cost £43½ million and to require until 1961 to complete. The cost per unit at the receiving sub-stations was estimated to be 0·2525d. for the initial development and 0·1703d. when the scheme was complete.

In comparing the relative claims of Kariba and Kafue the consulting engineers were gravely hampered by the paucity of topographical and hydrological information on Kafue Gorge, but it was evident that Kariba had much greater potentialities and that it would ultimately be the more economical source of power; indeed, the potential development of Kafue appeared to be such that its output would be fully absorbed by the initial demand. If, therefore, Kafue were put in hand first it would probably be necessary to commence Kariba before Kafue was finished. On these grounds it was recommended in the first report that Kariba should receive priority of construction but that Kafue should be investigated further.

Since that report was published no construction has taken place, but the power-supply situation in the Northern Rhodesian copper belt has since become such that in October 1951 the Government of Northern Rhodesia asked the consulting engineers to make a detailed examination of the potentialities of the Kafue in order to ascertain whether 200 MW of firm power could be rendered available at an earlier date than that given for the completion of the first stage of the Kariba scheme. At present the copper mines depend for their power mainly on coal from the Wankie colliery in Southern Rhodesia, involving a 600-mile haul, and limitations of supply from this colliery have made it necessary to generate some 30 MW by burning cordwood cut from the local bush—an expensive procedure which cannot be continued indefinitely owing to the increasing distance of haul between the bush and the mines. In spite of these difficulties the generating capacity in Northern Rhodesia is expected to be increased to 187 MW in 1960 but even so this will represent a shortage of 40 MW. The mining companies are negotiating for the import of 50 MW from the Belgian Congo to be available in 1957 for a period of five years, but it is evident that by 1960 power from some other source must be available if development is not to be hindered.

In the report just issued, the Government of Northern Rhodesia has been given firm estimates of the power available and the period of construction required, and on the assumption that an early supply of power to the copper belt is of primary importance the report confirms that the Kafue scheme ought to render a supply available a year or two before the Kariba scheme. It is estimated that the plant could commence to generate in five years from the date of the order to proceed and could be in full service in 6¾ years.

One of the main problems in developing the Kafue is that of storage, for the capacity of the gorge itself is limited, and upstream of the gorge the river flows for about 200 miles through a great flood plain—the Kafue Flats—the evaporation from which would be excessive. Upstream of this plain it may be possible to regulate the river by building a dam at the Meshi-Teshi gap, but much more investigation is necessary before it can be said how much of this regulated water would in fact reach the Kafue Gorge. Data on river flow in Kafue Gorge, too, are too scanty to

* See "Kariba's Part in Central African Development." WATER POWER, September 1951, page 324.

permit firm conclusions to be drawn although much work has been done with such data as are available. In consequence it is stated that 200 MW of firm power cannot be guaranteed with the present proved storage facilities, but a conservative estimate indicates that in the driest year a firm capacity of 186 MW at 80 per cent. load factor could be maintained. An initial development of 257 MW at 80 per cent. load factor, with a utilisation of over 99 per cent., is recommended, and seeing that further study may show the ultimate potentiality to be greater than can as yet be assumed, it is proposed that the scheme shall be flexible so that its capacity can be increased to 418 MW at 80 per cent. load factor by the installation of additional plant.

The average gross head available is 1,936 ft. developed over a distance of 13½ miles, but it is impracticable to utilise this in a single stage because of the absence of sufficiently high ground in the vicinity of the power station to accommodate a surge chamber. It is proposed, therefore, to divide the development into two equal stages by placing a station in the gorge of the Keshya River, a tributary of the Kafue, and a second at the lower end of the Kafue Gorge. These two stations would operate under equal heads and would have identical equipment, each having four 43 MW sets initially, with provision for the addition of two further similar sets at each site.

The output from the two stations would be handled by a central switching station and transmitted north and south by 220 kV single transmission lines.

Provided the assistance of the mining companies in tunnelling is available, and their reputedly low tunnelling costs achieved, the capital cost should be £27·6 million, including transmission, and the cost of power at the receiving substations 0·258d. per kWh. The scheme is designed for integration with any future development at Kariba, in which event the greater storage capacity at Kariba would react favourably on operation at Kafue and would increase its output.

We hope to give an extended summary of the report in our April issue.

St. Lawrence Seaway

FROM recent technical press reports it appears that the St. Lawrence Seaway project is moving toward its final stage, and that the outlook for construction at the present is somewhat brighter. To date the start-up of construction has been somewhat hampered by the resistance built up in the United States toward the construction of an international seaway with U.S. Federal aid. At the present time hearings are being held in the U.S., and more favourable reaction has been obtained.

The proposed construction of the international rapids would include two dams, one of which would be located at Iroquois Point, and controlling the flow of Lake Ontario, and the other at the upper end of Barnhart Island. The Iroquois dam would keep the Lake Ontario level at elevation 242 ft. and the tail-water at elevation 154 ft., developing a minimum head of 88 ft. With the available flow this should generate about 2,200,000 h.p., with an annual output of over 12 billion kilowatt hours. The cost of this part of the project based on 1950 estimate will amount to $537,000,000, of which roughly half should be carried by the U.S. Federal authorities, and the other half by the Province of Ontario. It is intended to build a 27 ft. navigable channel from the tide waters of the Port of Montreal to Lake Ontario. Locks would be 800 ft. long, 30 ft. wide, and 30 ft. deep above sills. According to the present layouts large amounts of dredging are required, and dyke work is involved in the project. The new U.S. Government might take a more favourable view of the St. Lawrence Seaway as it is to serve to a great extent the defence needs of both Canada and the U.S.

The procedures are largely influenced by the recent iron-ore developments in the Ungava region, the ore of which gravitates to the smelters at Lake Superior. The hearing of opposing parties of the Seaway project has also taken place and it is interesting to note that for the first time a large group of railways has opposed the project. Minor companies using the St. Lawrence flow to a certain extent are also anxious to defend their rights and invested capital.

Grande Dixence

THE Grande Dixence hydro-electric scheme, one of the most impressive pieces of engineering in Europe, is now being pushed ahead as quickly as possible. This scheme, which will take 15 years to complete, envisages the collection of water from some twenty glaciers and diverting it through 80 miles of tunnels to a reservoir where it will be available for winter use.

It will constitute the highest-altitude hydro-electric scheme in Europe, and the dam, 900 ft. high, will be the tallest in Europe. The storage dam, at Cheilon, will have a capacity of 400 million cu. ft. The final cost of the scheme is estimated to be over £80 million, all of which is being met by private enterprise.

The scheme has been necessitated by the shortage of winter power which at present has to be imported from France. When the scheme is completed it will contribute some 1,600 million kWh per annum to the Swiss network, mostly in the winter months.

Much has been done at Grande Dixence since work started two years ago. A mountain road capable of taking heavy lorries, has been built, 19 miles long and achieving a height of 7,000 ft. above sea level; and a new village, Prazfleuri, stands at 8,450 ft. above sea level, with dormitories, offices, a restaurant and a cinema. A cableway has been constructed, much equipment assembled and the tunnelling work commenced. It is understood that some of the generating equipment will be put into operation in 1957.

Austrian Progress

THE two dams closing the valley below the Pasterze Glacier, Austria, at 6,600 ft. above sea level to form an additional storage basin for the Glockner-Kaprun Tauernkraftwerke power plant have been completed recently after three and a half years' building. The basin holds 2,400 acre-ft. of water which is led to a second basin (the Mooserbodenstausee) by a seven-mile long tunnel and will increase the output of the power plant by 187 million kWh a year. The larger of the two dams is 300 ft. high and its crest 558 ft. long; the other is 137 ft. high and 565 ft. long.

Work on the Weisseesperre, which is some 7,500 ft. above sea level and one of the most difficult to build, is nearing completion. The storage basin will raise the capacity of the Stubachtal Tyrol group of power stations supplying the Federal Railways by

nearly 40 million kWh to about 230 million kWh annually. Expansion of power plants in Austria has enabled the country to increase consumption from 2,670·4 million kWh in 1947 to 4,874·5 million kWh in 1951.

New Spanish Station

THE Spanish Empresa Nacional Hydroelectrica de Rubergarzora has recently put into service the second power station in the hydro-electric system that is being constructed on the higher reaches of the Noguera-Ribergarzora. The power in the turbines is stated to be 6,100 h.p. and the average annual production is expected to reach some 23 million kWh. The third station is shortly expected to go into service and this will, it is hoped, greatly help power supplies during the winter.

British Hydromechanics Research Association

THE annual report of the British Hydromechanics Research Association reveals encouraging progress since the Harlow laboratory was opened in 1951, both in the equipment and utilisation of the laboratory and in increased membership. Researches to which we referred in an article in our April 1952 issue have been continued, and an important new investigation has been undertaken on the hydraulic transport of solids. In connection with the spillway tests, experiments are in progress on a model of a system of syphons which it is proposed to build on to an existing overflow spillway in order to raise the normal water level of the reservoir and thus increase its storage capacity, while at the same time permitting the same maximum flood discharge at the highest safe water level. Last September a week-end conference was held at Cambridge. Two of the papers read at this conference were of immediate interest to water-turbine engineers; one of them was published in our January issue and the other will appear shortly.

Canadian Water for Canada

THE proposal by the Aluminium Company of America to the Canadian Government to take water from the Yukon River over the international frontier to supply power to an aluminium works in Alaska has been rejected on the ground that Canadian water should be used for the benefit of Canadians. It was decided to dam the river and to convey the water through two large tunnels to two underground power stations near Skagway. Each station would have had a capacity of 600 MW and the scheme would have cost 400 million dollars.

T.V.A. Boone Dam Dedicated

THE Boone dam on the south fork of the Holston River is the latest of the Tennessee Valley Authority's dams to be completed and was officially dedicated recently. It is 160 ft. high and 1,532 ft. long, and will provide a storage of 210,000 acre-ft. at a maximum level of 1,385 ft. Three 25,000 kW generating sets are installed, operating under a head of 90 ft. It is the nineteenth dam to be completed by the T.V.A. and the twenty-ninth major dam on the T.V.A. system.

Another important structure now being built on the Holston River is the Fort Patrick Henry dam near Kingsport, which will be 95 ft. high and 670 ft. long, impounding 29,850 acre-ft. at a level of 1,263 ft. It will supply two 18,000 kW sets at a head of 61 ft. Other dams recently completed in the upper Holston area are the South Holston and the Watanga.

Owen Falls Finances

THE Uganda Government is seeking powers to borrow a further £7 million sterling to enable the major projects of the Uganda Electricity Board to be carried through without unnecessary delays. It is considered that this loan is necessary to meet the increased cost of building the Owen Falls dam at Jinja, Uganda's share of the cost of constructing a 240-mile power line from the dam to the copper deposits at Kilembe, and the cost of installing new generators to meet increased requirements.

The British Foreign Office has announced that Egypt is to bear that part of the cost of the scheme necessitated by the raising of the level of Lake Victoria for storage.

New Zealand Waikato Station

THE proposed hydro-electric station at the Huka Falls and Aratiata Rapids should have a capacity of 100,000 kW and be capable of contributing a revenue of one million pounds per annum for the State Hydro-Electric Department. This was stated by the Minister in charge of the Department, Mr. W. S. Goosman, at the conference of the New Zealand Electrical Supplies Association at Rotorua. Mr. Goosman explained that the work being carried out at the Huka Falls was purely investigatory and would interfere as little as possible with the natural beauty of the river.

Turkish Consumption

TURKEY consumed 883,000,000 kWh of electricity in 1951, of which 839 million kWh was generated by thermal electric plants and 41 million kWh by hydro-electric installations. Industrial plants used 610 million kWh, followed by domestic users with 150 million kWh, street lighting 26 million kWh and transport 18 million kWh. The installed capacity of Turkey's electric power plants in 1951 was 34,000 kW of hydro-electric and 406,250 kW of thermal plant. Fuel consumption totalled 408,192 metric tons of coal, 222,848 tons of lignite and 24,000 tons of fuel oil.

Uruguay Project

FAR-REACHING electrification plans to free Uruguay from the cost of purchasing fuel abroad are contained in a measure which the Government submitted to Congress on November 29. It is proposed to build a hydro-electric plant on the Rio Negro at a cost of 165 million pesos (£23,000,000). The Government proposes to raise the money by a loan from the International Bank. Later, still larger works are projected at Salto Grande.

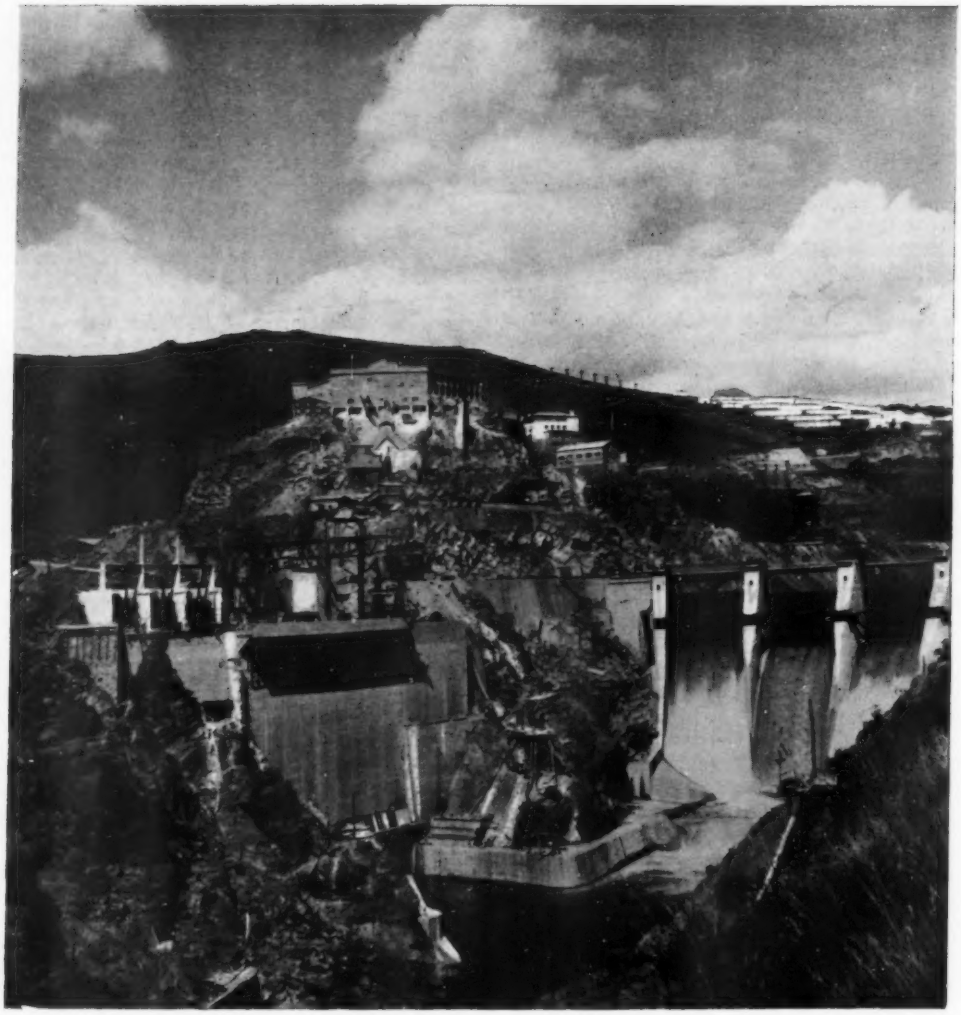


Fig. 1. Salto de Castro dam and power house

Salto de Castro

A description of a scheme on the Spanish/Portuguese border with special reference to the two 40 MW Francis sets. The first unit is in operation and has what is believed to be the largest fabricated runner yet built in Europe.

SITUATED virtually on the Spanish-Portuguese boundary, the Salto de Castro hydro-electric station constitutes the latest development which the Iberduero S.A. have initiated in their long-term plan for the full utilisation of the hydro-electric potentiality of the River Duero.

This river rises in the Moncavo hills of Central Spain, but hydro-electric development is not practicable until after it has passed the town of Zamora and approaches the Portuguese frontier. Near Zamora, the Duero is joined by the Esla river, and just above the junction Iberduero have constructed a large reservoir on the Esla of 1,200 million cu. m. capacity.

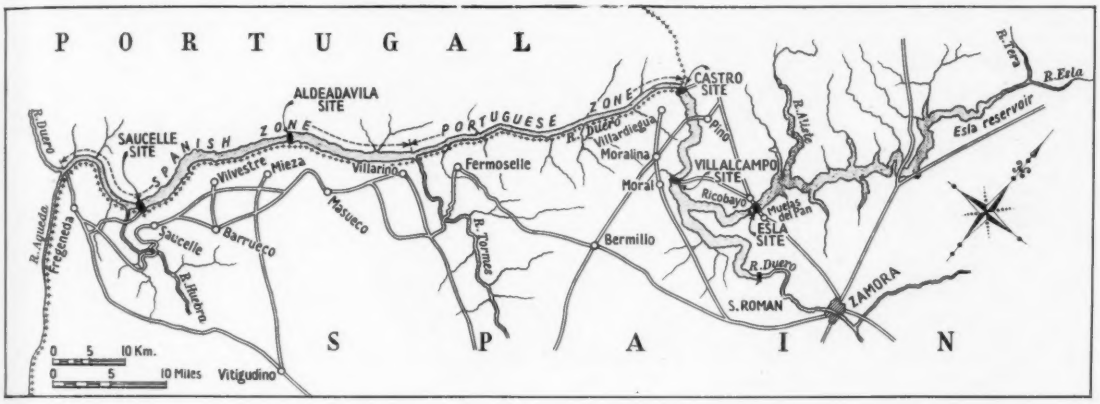
The Esla station is built at the foot of the dam and contains four vertical Francis turbines, each developing 51,000 h.p. at 187 r.p.m. under a net head

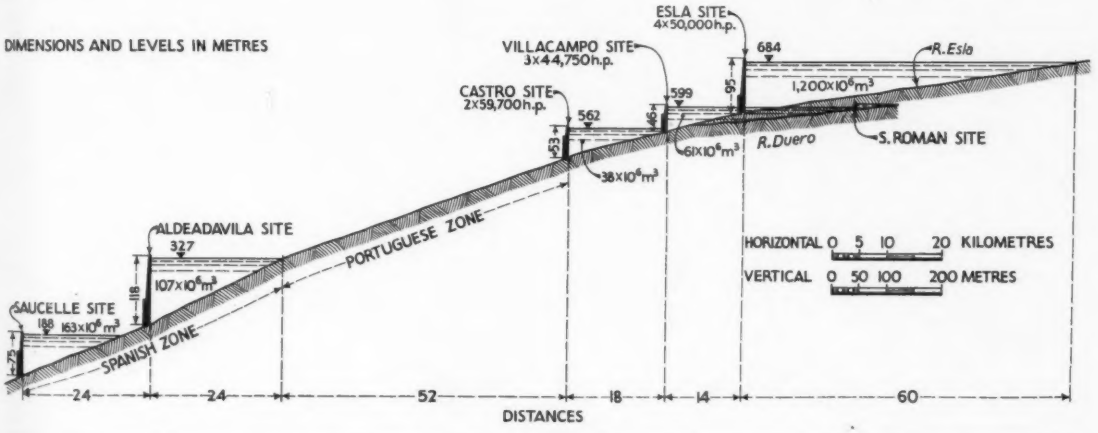
of 85 m. The discharge from this station joins with the River Duero approximately 10 km. farther on as will be clearly seen from Fig. 2. Four kilometres downstream from this junction, Iberduero have constructed their second large station, Villalcampo, in which there are three vertical Francis turbines of 45,000 h.p. each, running under a net head of 40 m.

The Castro project is located a further 18 km. down the river on the actual borderline with Portugal. Below this point, the Duero swings abruptly south and becomes the boundary between Spain and Portugal, and the rights of hydro-electric utilisation of this section have been regularised by treaty. The first 52 km. are to be developed by Portugal and has a total fall of 195 m., thereafter is the Spanish zone of approximately the same length but with a total available head of 201 m. After this the course of the river turns again to westward through Portugal to reach the sea at Oporto.

The arrangement of the Castro development is shown in the vertical section and plans reproduced in Figs. 4, 11 and 12. This project was commenced in early 1948 but it was originally intended that the station should lie at the foot of the dam. However, the narrowness of the river at this point rendered this arrangement impracticable and it was decided to take advantage of a small ravine which joins the main river immediately below the dam and to place the station at the foot of a second dam erected across the mouth of this ravine (Figs. 1, 4 and 9).

The main dam across the River Duero is a concrete construction and has the spillway divided into four sections as shown in Fig. 4. At the top of the dam electrically operated sector gates are arranged between





Locations of stations	Heights of dams m.	Capacities of reservoirs millions of cu. m. Total	Useful	Number of sets	Gross head m.	Output h.p.	Annual power output millions of kWh
Esla	95	1,200	1,120	4	85—44	200,000	430
Villalcampo ...	46	61	53	3	37—39	134,250	360
Castro	53	38	20	2	40—38	119,400	320
Aldeadavila ...	118	107	82	—	139—141	581,400	1,582*
Saucelle ...	75	163	56	3	62—60	232,560	698*
Total ...	—	—	—	—	—	1,267,610	3,390

*Projects only

Fig. 2. Map, profile diagram and particulars of the Esla and Duero developments

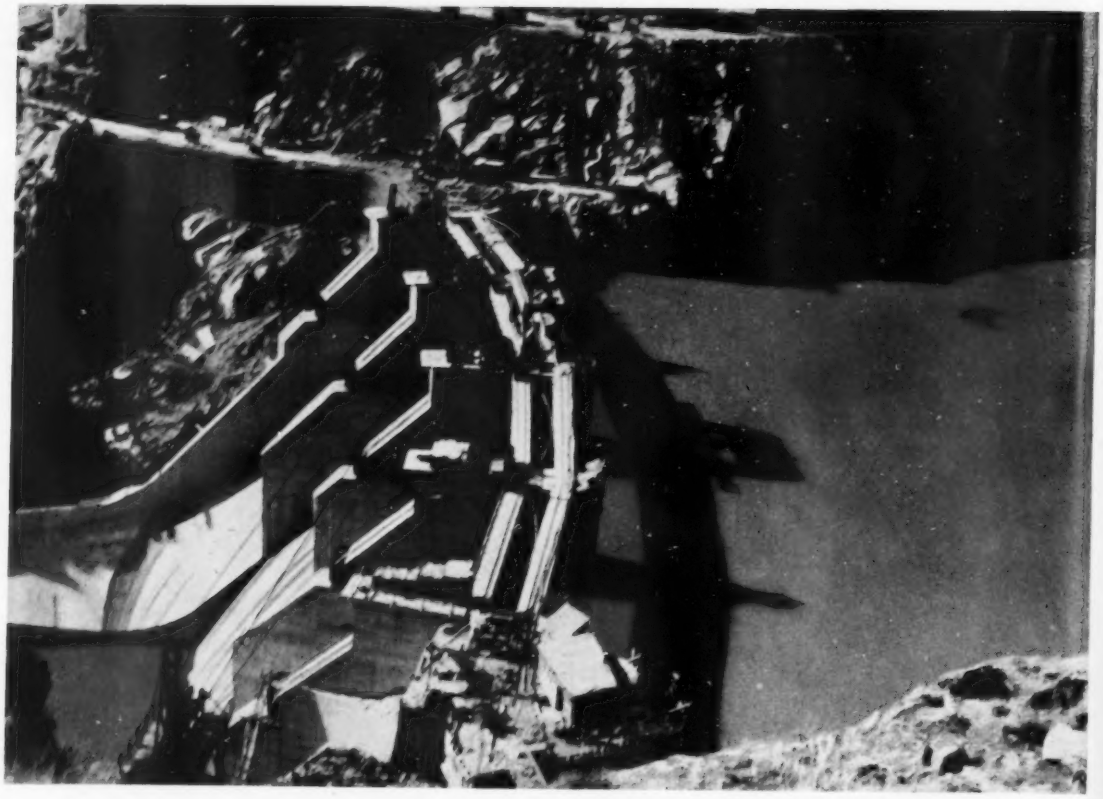
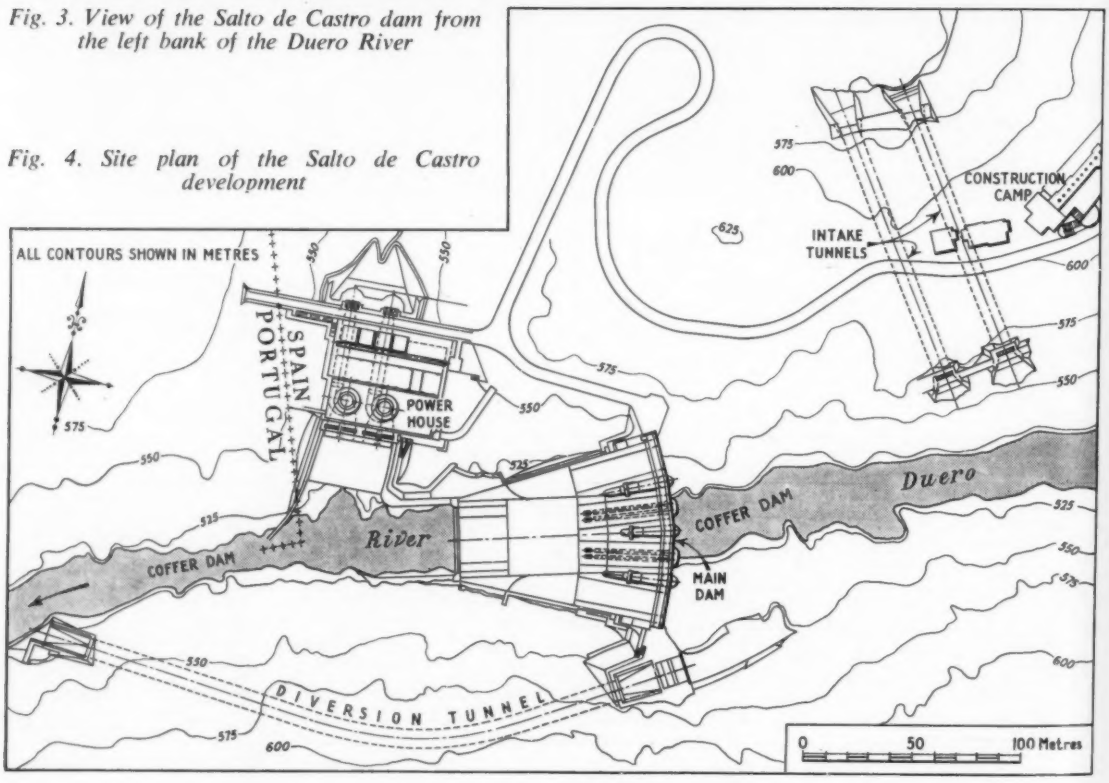


Fig. 3. View of the Salto de Castro dam from the left bank of the Duero River

Fig. 4. Site plan of the Salto de Castro development



reinforced-concrete piers (Fig. 5). These fabricated steel gates were made in Spain and are 18 m. wide and 11 m. deep. Stoplogs are provided in front of each of the gates to permit maintenance on the main sector gates when desired.

From the top of the dam to river-bed level there is a drop of approximately 46 m., and with such a head it was essential to dissipate the energy effectively during flood. The spillway, as will be seen from Figs. 4 and 5 is divided into four sections, the outer sections being banked steeply inwards. This curvature, together with the formation of a hydraulic jump, ensures a turbulence that dissipates the energy before the water reaches the power-house tailrace outlets.

Fig. 12 shows the layout of the power station. The intakes are provided with semi-cylindrical screens which are removable for maintenance and cleaning, and the intake gates can be operated in emergency conditions from the power-station control room.

The tailrace is provided with stoplogs, and a dewatering system is available for pumping out the suction tubes.

The method of construction to carry the load from the generator to the foundations is a very interesting feature of the design. It allows erection work on the alternator to proceed at the same time as the turbine (Fig. 13) is being erected, and also affords great freedom of access to the turbine and its auxiliary equipment.

As will be seen from Fig. 11, the clients' arrangements for off-loading at site were well laid out. The lorries bringing the turbine and alternator parts could drive under an overhead travelling crane having rails running along the dam. This crane brought the

Fig. 5. View of the four spillway sections and tainter gates

Fig. 6. A view upstream of the power station showing the discharge from the intake tunnels on the extreme left

machinery cases underneath the gantry crane, which then lowered these parts on to the alternator floor at a level of 541 m. The two 240 ton station cranes could then lower the turbine pieces down the turbine floor level.

The Castro station consists of two vertical Francis turbines each developing 59,000 h.p. under a net head of 37 m. The normal flow of the River Duero at this point is of the order of 300 cu. m. per sec., but as with all Spanish rivers, severe flood conditions are experienced. These normally occur on the Duero in the latter half of December. A hydrological survey found the frequency of the floods to be as follows:—

Up to 1,200 cu. m. per sec.	Once every year.
Up to 3,000 cu. m. per sec.	Once every 5 years.
Up to 5,000 cu. m. per sec.	Once every 30 years.

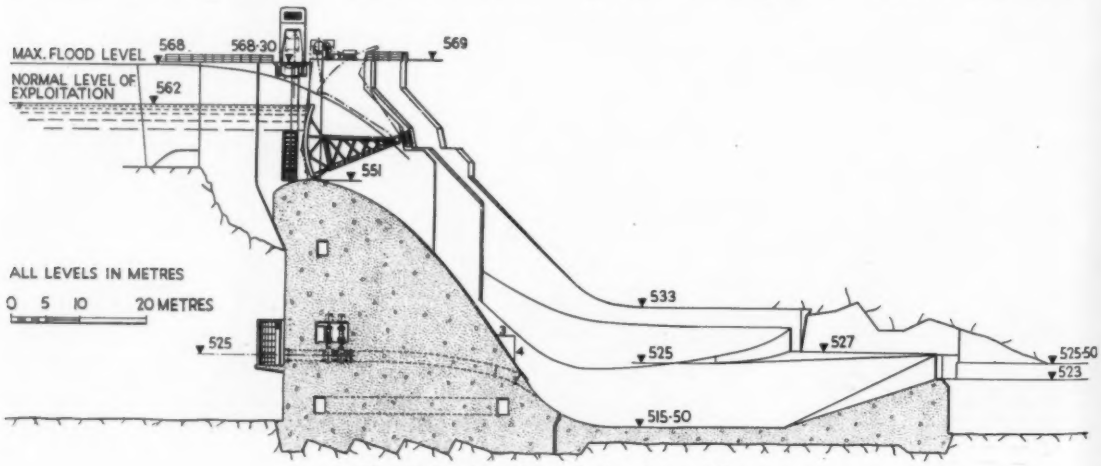


Fig. 7. Section through the dam spillway

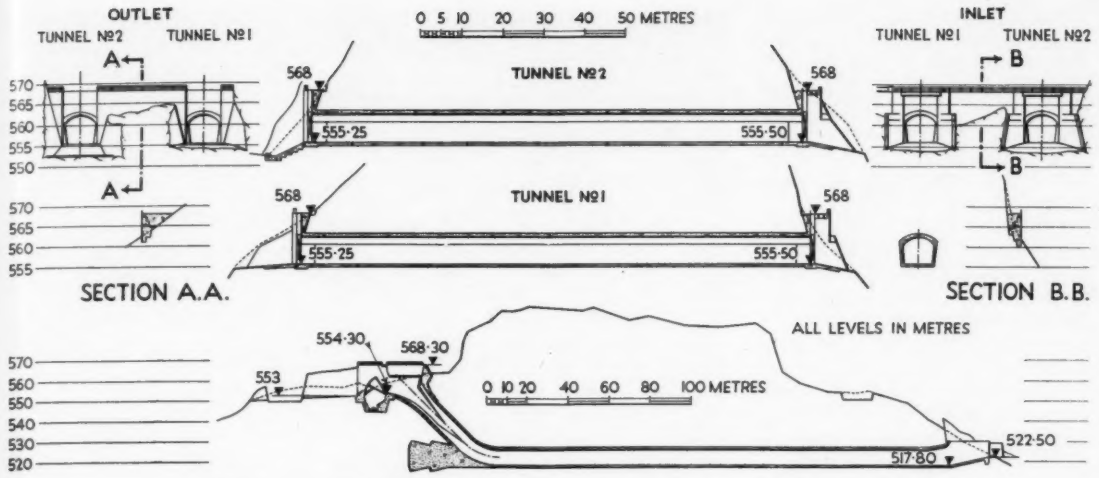


Fig. 8. Section through the intake tunnels and the diversion tunnel

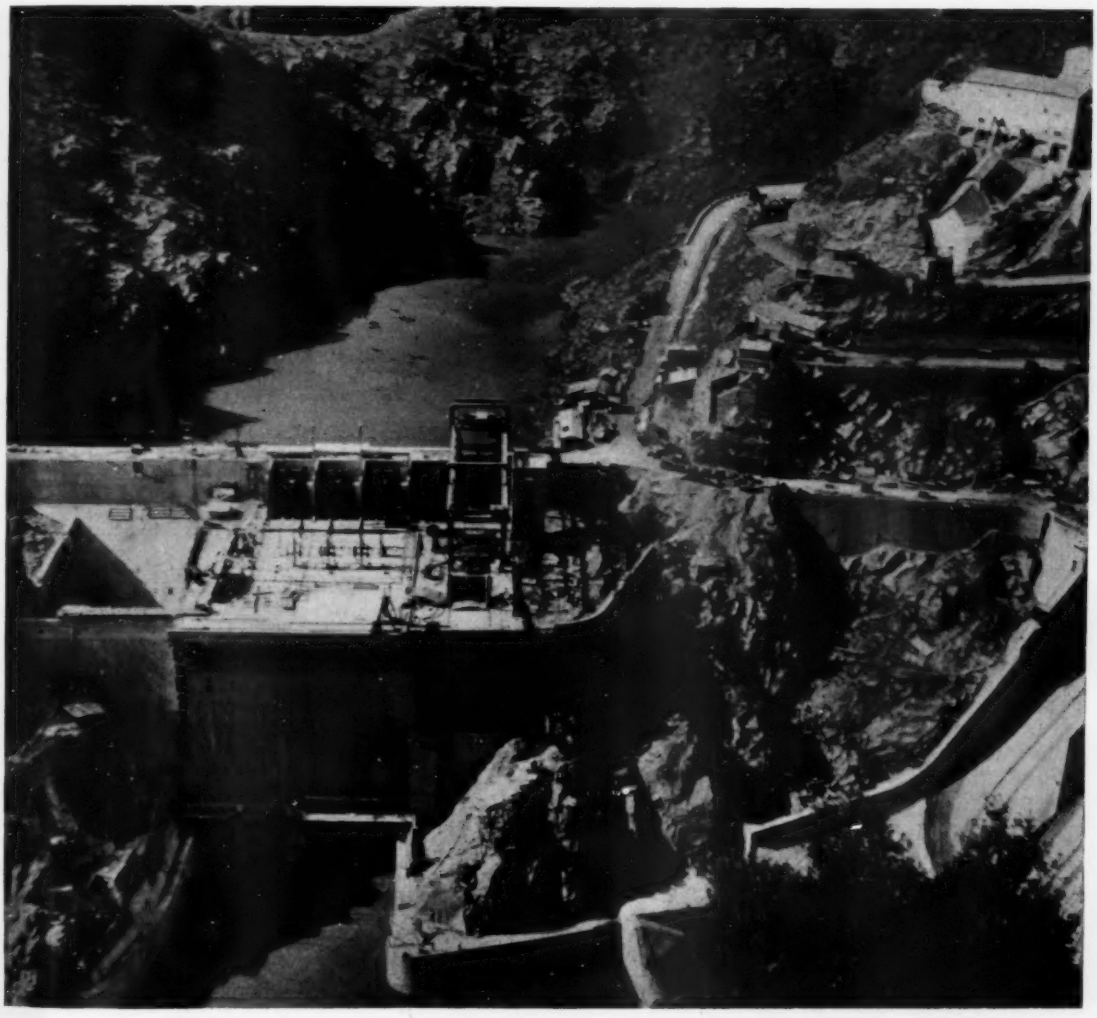


Fig. 9. Downstream side of the power station with part of the spillway on the right

During normal conditions the upper water level varies between 558 m. and 560 m. and the tailrace level between 522·7 and 524 m. During flood periods the water will discharge over the spillway at the 568 m. level and the tailwater level may reach a maximum of 558 m.

When the station was first being planned, the possibility of using Kaplan turbines was investigated, but it was decided that the variation in water level would not justify the extra expense, especially as these units are intended to operate on a high load factor, at which the Francis design achieves equal efficiency.

The fabricated turbine runner (Figs. 14 and 15) weighs 47 tons, and has a diameter of 3,400 mm. being, we believe, the largest yet built in Europe by this method of construction. The band, hub and the 16 blades are of cast steel, all these pieces being machined before assembly. Each blade was machined on a profiling machine and checked to jig.

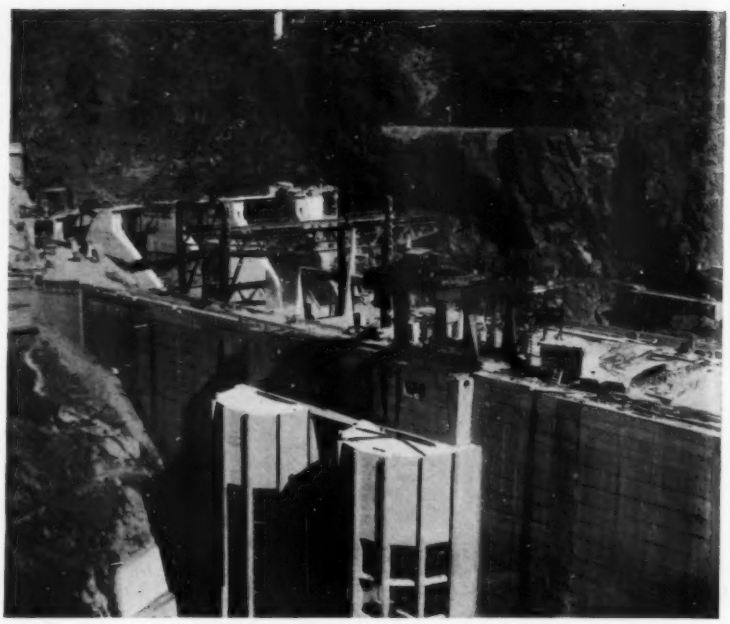


Fig. 10. Inlet structures for the two turbines

To assemble the runner the band was positioned on a large cylindrical bedplate and carefully levelled. The blades were then positioned by a template to obtain their correct spacing and openings; thereafter they were tack-welded first to the runner band and then to a temporary ring attached to a pillar which itself was located carefully on the vertical centreline

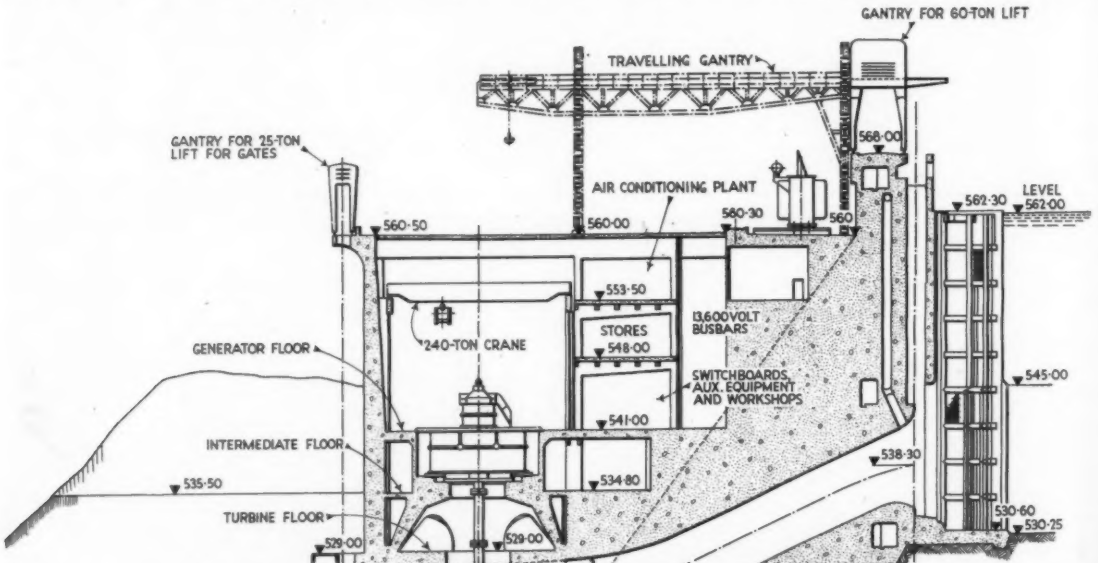


Fig. 11. Cross section through the power station

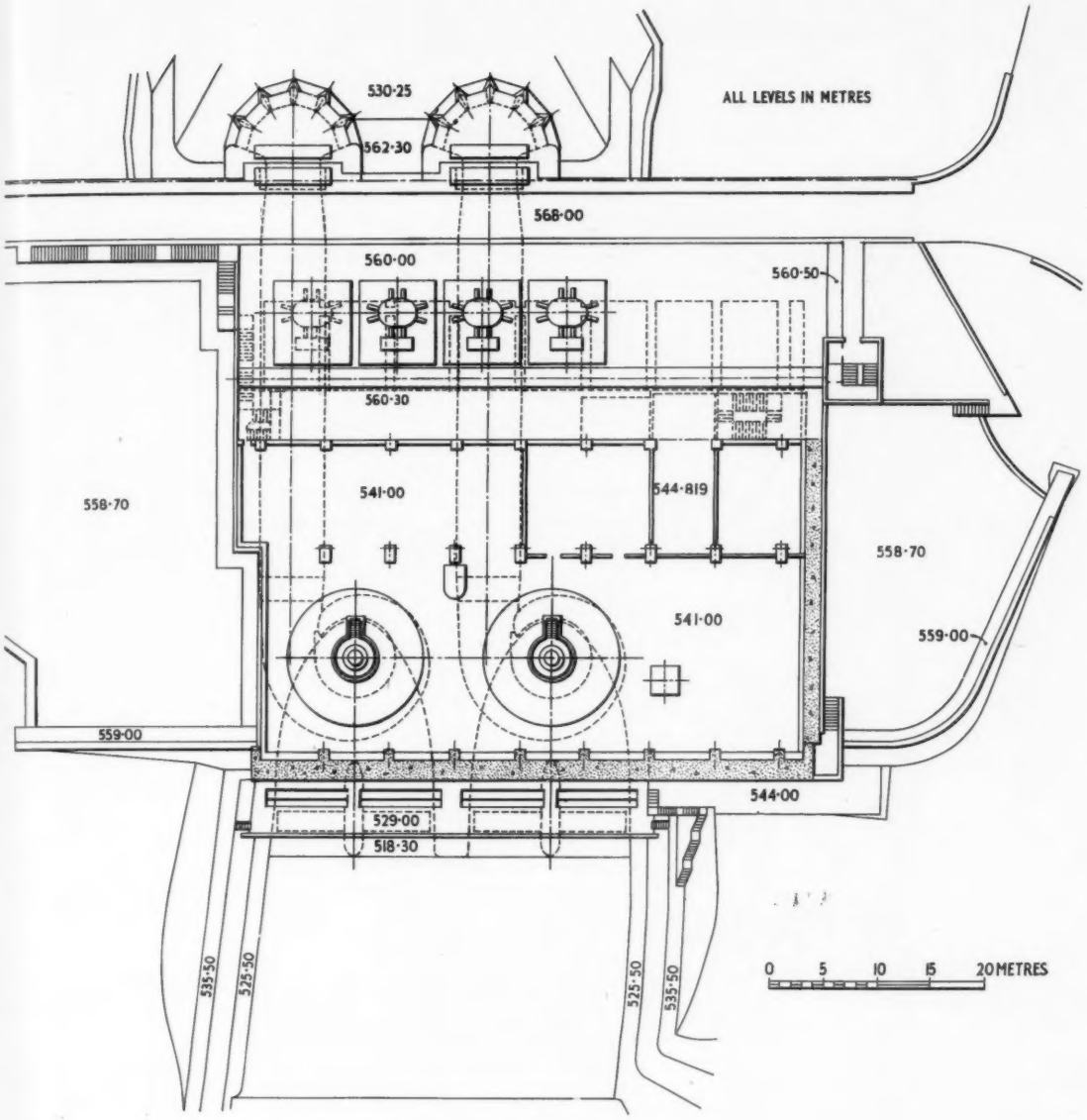


Fig. 12. Plan of the power station

of the runner. The runner hub was then lowered into position and the blades tack-welded to it. The openings between blades were re-checked and then the blades were welded finally to the band and to the hub. Great care had to be exercised throughout the welding and a special technique was adopted. After that the stainless-steel protection was welded on the outlet edges of the blades and band where cavitation might occur. The surfaces of the blades were ground to a fine finish before proceeding with the final machining of the band and hub. The runner band and hub are provided with stainless-steel wearing rings which are renewable, as also are the stationary rings facing them. Finally, the runner was statically balanced before dispatch.

The turbine shafting is made up in two sections to facilitate transport and to limit the crane-hook height. Even so, each section of shafting is 16½ ft. long and weighs over 27 tons.

The stayring had to be constructed in four sections as it was impossible to transport it as a single item. The overall diameter is 23 ft. and the four sections have a total weight of 57 tons. As will be seen from Fig. 16 the stayring consists of an upper and lower plate of mild steel between which are welded 12 cast-steel streamlined stays, the sections being fixed together with 2¼ in. diameter fitted bolts. When preparing the design of the stayring it had to be borne in mind that it would have to bear a weight of 2,700 tons of concrete, this being the permanent load of the concrete structure and the intermediate floors. Fig. 12 shows the intake arrangements. The penstock, 6·00

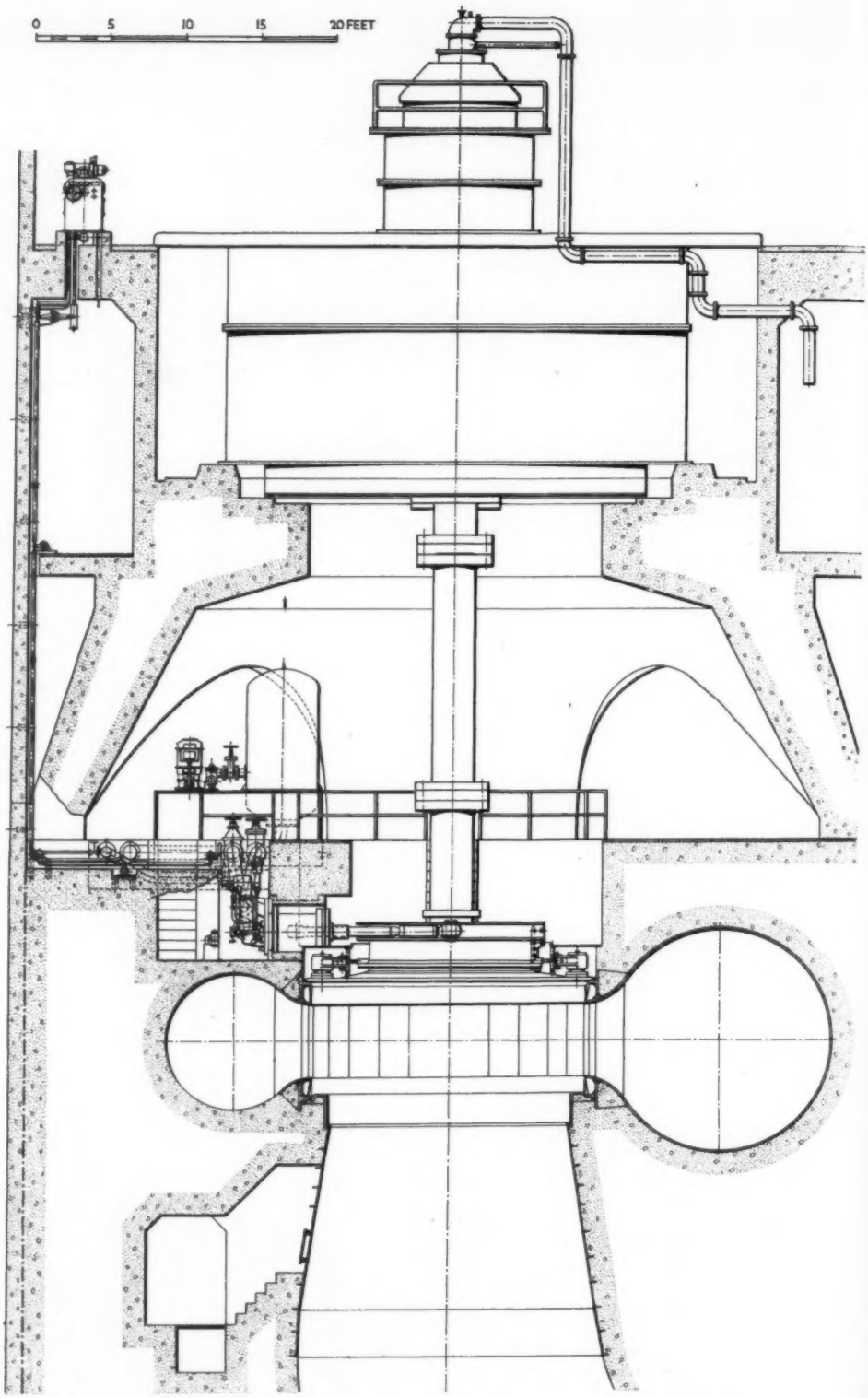


Fig. 13. Section through one of the 40 MW generating sets

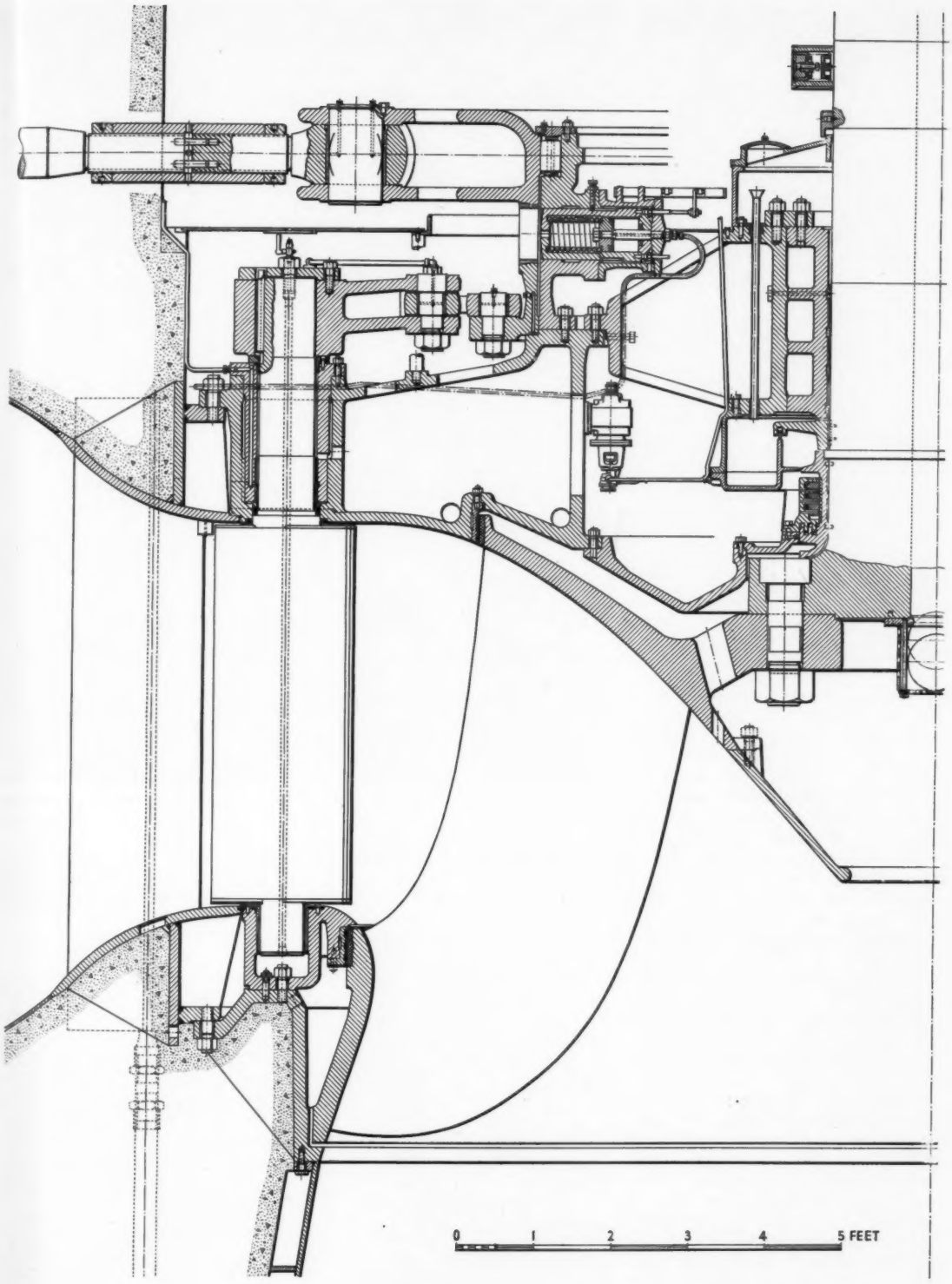


Fig. 14. Half section through Boving 59,000 h.p. turbine

m. in diameter, was lined with mild-steel plate and fitted with a taper section to join the inlet flange of the spiral casing. The inlet diameter is 5·645 m., the plates at this point being 1 in. thick. The plates for the spiral casing were rolled, bevelled and generally prepared in this country. They were dispatched plate small to the site where the Spanish workers did a most excellent job in welding and assembling the casing to the stayring.

There are 24 cast-steel guide vanes per set, each vane being fitted top and bottom with stainless-steel wearing plates where corrosion effects are most likely to occur. Furthermore, rubber strips were fitted to the leading edge of each guide vane to ensure perfect sealing when the turbine sets are shut down.

The lubricating system to the turbine shaft bearing consists of automatically controlled a.c./d.c. pumps taking oil from a lower oil pot and delivering it to the oil pot situated on top of the bearing. The oil from this pump flows by gravity through the bearing to the lower oil pots.

The turbine shafts were supplied with a special type of sealing device known as the Huhn packing, which consists of a number of carbon rings held against the shaft with garter springs. The rings are of triangular section and are arranged in pairs in such a way that when the springs press them against the shaft they are also wedged against the sides of the grooves. The shaft is protected against wear by means of a renewable liner made in two halves bolted together. This form of packing reduces the amount of leakage to a very small amount even when the tailwater level is high.

Fig. 15. Runner of one of the 59,000 h.p. Boving turbines in the works of Markham & Co. Ltd.

The governing system on the Castro turbines consists of the actuator, servomotor and electrically driven oil pumping set. The actuator is located on the generator floor and is connected via the regulating shaft to the main servomotor regulating valve, receiving oil pressure from the main pumping set. The pendulum on the actuator is driven by a synchronous motor which is supplied with current direct from an auxiliary generator mounted on the main alternator shaft, with which it rotates in step. The movements of the actuator caused by changes in speed of the turbine are transmitted to a pilot valve which in turn controls the regulating valve in the actuator. This latter valve determines the setting of a small servomotor located inside the actuator. The movements of this servomotor go direct to the regulating valve on the turbine servomotor. Thus the actuator has only to supply a small amount of power necessary to operate the regulating valve on the servomotor and this is the reason for what would otherwise appear to be its rather small size.

The main regulating valve is mounted on the servomotor cylinder cover and controls the movement of the piston, which is coupled by a connecting rod to the regulating ring controlling the guide-vane openings.

A compensating device is attached to the pilot valve in the actuator to prevent overtravel, which in turn might cause hunting. The piston on this compensator moves very slowly in its cylinder so as to eliminate any irregularity in action due to friction. The amount of damping produced by this compensating device can be adjusted.

All the controls for starting and stopping the machine are located on the actuator.

A few words are necessary to explain the operation of the oil-pumping set, which consists of a vertically mounted electrically driven screw-pump (Imo type) placed on top of a large-capacity tank. Oil is delivered through a non-return valve into a large air vessel, the usual safety and unloading valves being located on top of this tank. Fitted to the side of this air vessel is an automatic air compressor operated by pressure oil which maintains the required oil level in the air vessel. Oil from the air vessel is taken into the main 8 in. pressure line and arrangements can be

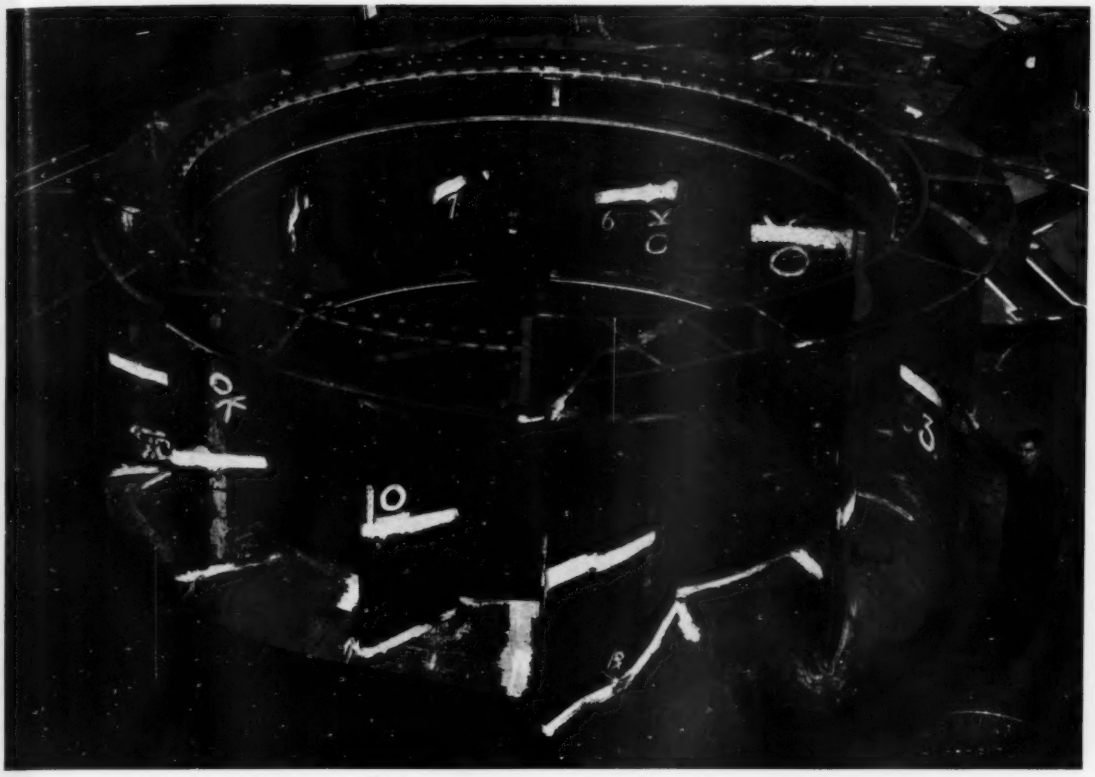


Fig. 16. Stayring of one of the 59,000 h.p. turbines

made for interconnection between the two sets. Various devices such as motor underspeed switches, pressure gauge, and alarm contacts are fitted on this pumping set to ensure the satisfactory and safe running of the whole unit.

The order for the Castro turbines was received by Boving & Co. Ltd. in late 1948, this firm being responsible for the design and drawings, while the actual turbines were made by Markham & Co. Ltd., of Chesterfield. The F.10 actuators in this case were made by Messrs. Karlstad Mekaniska Werkstaden, but arrangements have now been completed for them to be manufactured under Boving's supervision at the Clydebank works of John Brown & Co. Ltd.

The first parts for the Castro units were delivered in late 1950 and erection commenced in the spring of 1951. The clients took the main responsibility for the erection, but a supervisor engineer was sent out from England to assist.

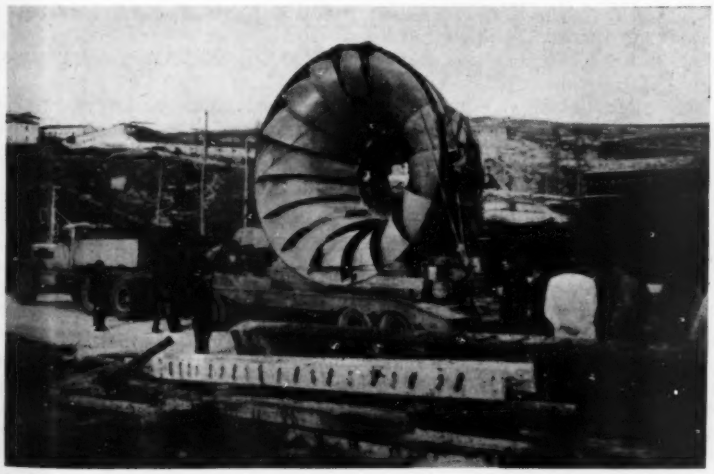


Fig. 17. The first runner in course of transport to site

The first unit started up at 5.5 a.m. on August 1, 1952, and ran with complete success, so that it was possible to proceed immediately with bearing trials. These in turn were also completely satisfactory and on August 2 it was decided to commence drying out the alternator. The unit ran satisfactorily throughout the next two days, and on Monday, August 4, it was put into commercial service. Since that date it has been operating at an average load of 43 MW. The generators are rated at 42 MW and were supplied by the International General Electric Co. Ltd. of New York.

We are indebted to Iberduero S.S. and Markham & Co. Ltd. for permitting us to reproduce the photographs.

Book Reviews

Electrical Development in New Zealand. By H. J. Beeche. Electric Power Boards and Supply Authorities Association of New Zealand, Bethune's Building, 154 Featherston Street, Wellington, C.I., New Zealand. 342 pp. Illustrated. Price 30s. post free.

The original inspiration for this book came from a suggestion made by Mr. Beeche, who was then Secretary-Treasurer of the Central Waikato Electric Power Board, to a conference of secretaries of Electric Power Boards that each secretary should write the history of his undertaking and forward it to the Association for record. It was soon found necessary to extend this suggestion to include the earlier history before the Electric Power Board's Act of 1918, and the result is a volume that must surely be unique for its authoritativeness and comprehensiveness.

The book is divided into three main sections. The first deals with early history up to and including the formation of the Electric Power Boards, and tells us, amongst many other things, that the first hydro-electric plant for public supply was installed at Stratford in 1898. In the second section the history, operation and statistical returns are given individually for every Supply Authority in New Zealand. The third section, which will be of the most immediate interest to our readers, describes the work of the State Hydro-Electric Department. A brief history is given of each power station, with a summary of its technical particulars, and developments in hand or projected are outlined.

One must not look for extended technical descriptions in this book, but a vast amount of historical, legal, commercial, administrative and technical information is available in a concise form. To those who wish for an accurate overall picture of the development of electricity supply in New Zealand this book can be unhesitatingly recommended.

Surveying and Field Work (Third Edition). By James Williamson. Constable & Co. Ltd., 12 Orange Street, London, W.C.2. 551 pp. 337 ff. Price 40s. net.

First published in 1915, with a second edition in 1938, this work on surveying has recently had its third edition; it will therefore probably require no special introduction. Although the third edition has been revised and enlarged, this operation was to some extent limited by the fact that all the plates and unbound copies of the second edition were destroyed by enemy action early in the last war. Recourse had therefore to be made to photographic reproduction of pages, during which opportunity was taken to make various corrections and improvements by the excision and replacement of sections. Notwithstanding the difficulties, the production has been particularly successful, the print, diagrams and illustrations being first class throughout.

A new chapter has been added on Hydrographic and Hydro-electric Surveying, the latter part of which refers to those methods of measuring and recording the levels and flow of water with which the surveyor engaged on hydro-electric development may have to deal; applications of ordinary surveying principles to hydro-electric subjects are touched on at convenient points in some of the other chapters, such as that on Setting-out Works. The new chapter describes the normal methods of determining the surface of ground below tidal and non-tidal waters by sounding line and echo sounding, and the normal methods of measuring and recording the flows of rivers and channels by various types of weir and by current meter. Some general notes are given for the guidance of the surveyor on the preparation of stage-discharge curves and flow-duration curves.

The work as a whole covers the basic principles and practice of surveying and levelling in the field (by chain, compass level, sextant and theodolite) as well as the equally important matter of plotting in the office. Attention is given in each section to errors which may occur and means of avoiding them or minimising their effects. Traverse surveying is given two chapters to one on triangulation, another chapter dealing with some basic survey, traverse and triangulation problems. Tacheometric surveying is extensively covered in four chapters, one of which is entirely devoted to the practical application of the simplified stadia method.

The work is intended as a practical textbook for technical students and a work of reference for surveyors, engineers and architects, and can be said to have achieved its overall purpose in an adequate and orderly fashion without becoming too bulky for convenient reference.

Hydraulic Research in the United States. National Bureau of Standards Miscellaneous Publications 205. Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. 200 pp. Mimeographed in paper covers. Price $1.00.

This publication gives a comprehensive list of hydraulic research projects in progress in the United States and Canada. The various contributing laboratories are taken in alphabetical order, and in each case the projects in hand are tabulated, the information given including the title of the project, for whom it is being conducted, the correspondent, the nature and description of the project, its present status and stage reached in the investigation, and publications made. A subject index gives an immediate picture of research in any particular field.

Interim Rules for the Evaluation of Restriking-Voltage Severity. The Association of Short-Circuit Testing Authorities (Inc.), 36 & 38 Kingsway, London, W.C.2. Price 5s. net.

When judging the short-circuit performance of a circuit-breaker the restriking-voltage severity is one of the factors to be taken into account. Difficulty arises when it is necessary to compare the severity of circuits that produce restriking-voltage transients having widely different wave-forms. A method of overcoming this has been evolved by the Association of Short-Circuit Testing Authorities and is being considered by the International Electro-technical Commission for incorporation in the next edition of I.E.C. Publication No. 56 "Specification for Alternating Current Circuit-Breakers." Minor modifications suggested by the I.E.C. have been incorporated, and, pending issue of the I.E.C. publication, a method of evaluation of restriking voltage severity is set out in these Interim Rules to provide a means whereby comparisons may be made on a uniform basis during the testing of circuit-breakers in A.S.T.A. stations.

Fig. 26. The completed dam from the right bank

The Bau Muggeris Dam

In this final article the author discusses the advantages of the cellular type of dam in comparison with the solid gravity type

By DR. ING. CLAUDIO MARCELLO

CELLULAR dams of the various types, as compared with solid gravity dams, generally show the following advantages:—

a. lesser uplift pressures both on the foundations of the dam and in the mass of the concrete;
b. better stability against sliding;
c. ready dispersion of the hydration heat of the concrete;
d. considerably less volume, ensuring a shorter constructional period assuming concreting plants of equal capacity;
e. lower cost: this feature, however, may vary within wide limits in accordance with the characteristics of the dam.

The structural characteristics of the Bau Muggeris dam were studied by the author with a view to obtaining a cost reduction corresponding approximately to the reduction in volume. Thus, the shape of the cavities and the thickness of the buttresses were so selected as to minimise the use of forms and to ensure uniform profiles without causing difficulties in transport or in placing the concrete, such as might arise from adopting steel scaffolding or from greatly reducing the thicknesses. By these means, in the case of Bau Muggeris the increase in the unit cost of the concrete, in comparison with a solid dam, was kept within the limit of 1 to 2 per cent.

It is perhaps useful to take this opportunity to make a more detailed comparison between the costs of a cellular dam and a solid dam, with special and direct

reference to the type of structure adopted at Bau Muggeris. It should be understood, of course, that the unit costs of the various types of cellular dams may vary within very wide limits. The economy in volume afforded by an element of the dam under consideration, compared with an element of a solid gravity dam of equal width, is shown in the diagram as a function of the height of that element. Since the economy in volume that can be reached in the whole dam structure changes in relation with the profile of the ground at the dam site, the diagram shown in Fig. 28 refers to an assumed triangular section and an assumed trapezoided section of the gorge, aiming to give some limit values within which most of the practical problems may be included.

It is to be understood that the increase of the unit price of the concrete for a cellular dam as compared with a solid dam depends chiefly on three factors:—

a. extension and shape of the forms required for concrete placing;

b. the different layout of the two structures, with a greater " pour density " for the solid dam compared with the cellular one;

c. Possible different cement content required for the concrete in the two cases.

a. Formwork: We have determined the area of the formwork required for the pour of 1 cu. m. of concrete in the different types of dam under consideration, and obtained the diagram shown in Fig. 29. It is evident that the 0·18 to 0·20 sq. m. of formwork required for a solid gravity dam (assuming the pouring of the solid dam as being divided into monoliths of about 10 m. in side, computing forms on only two sides thereof, in accordance with usual good practice) for a height of about 60 m., are faced by 0·38 sq. m. and 0·90 sq. m. respectively for the Bau Muggeris dam and for the Huelches dam (Argentine), the latter being a derivate of the Noetzii type dam with further reduction of thickness. The cellular dam of the Bau Muggeris design requires therefore about 0·20 sq. m. of formwork per cu. m. more than the solid dam.

Computing the cost of 1 sq. m. of steel formwork in place as equivalent to 2·5 cu. m. of concrete approximately, and considering amortisation as normally charged on 75 to 100 re-uses (keeping due account also of losses of material used for support) the charge for one sq. m. of forms corresponds to about one thirtieth to one fortieth of the charge of 1 cu. m. of concrete.

The charge for labour for placing 1 sq. m. of forms corresponds to about one thirtieth of the cost of one cu. m. of concrete, so that the total charge for one sq.

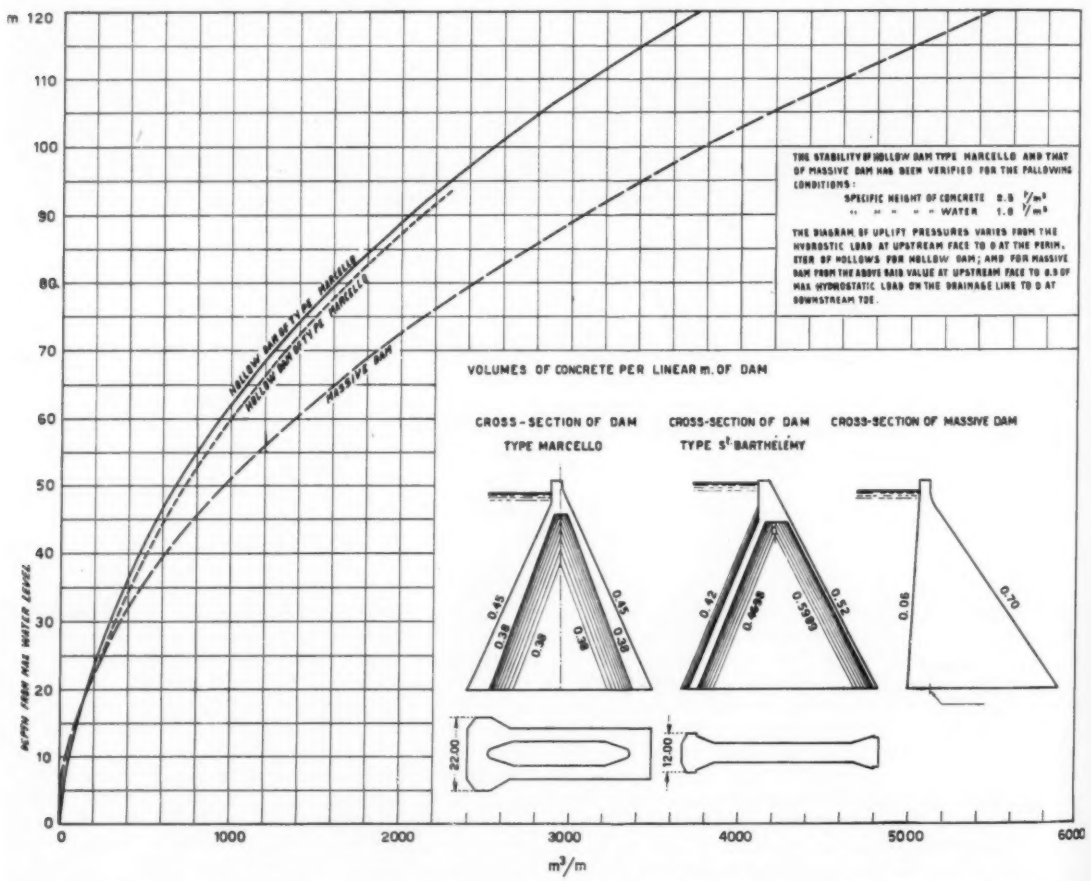


Fig. 27. Comparison between the concrete volumes belonging to two types of hollow-section dams (Bau Muggeris and St. Barthélemy) and to a solid gravity dam as a function of the height of the structure

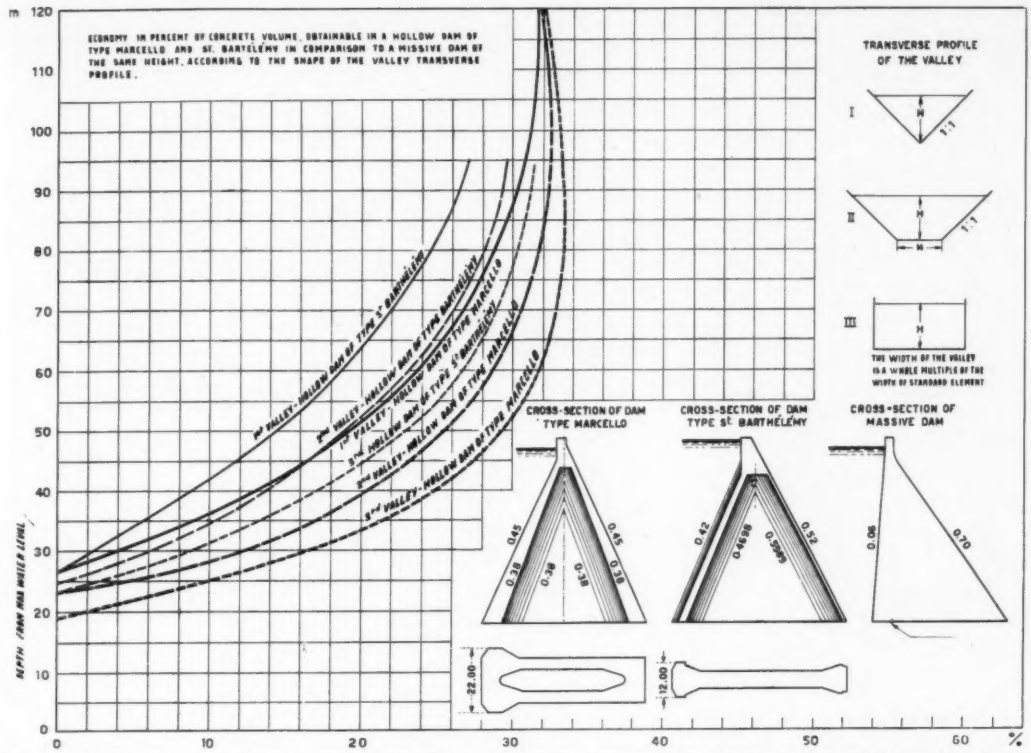

ECONOMY IN PERCENT OF CONCRETE VOLUME, OBTAINABLE IN A HOLLOW DAM OF TYPE MARCELLO AND ST. BARTHÉLEMY IN COMPARISON TO A MISSIVE DAM OF THE SAME HEIGHT, ACCORDING TO THE SHAPE OF THE VALLEY TRANSVERSE PROFILE.
TRANSVERSE PROFILE OF THE VALLEY
I
II
III
THE WIDTH OF THE VALLEY IS A WHOLE MULTIPLE OF THE WIDTH OF STANDARD ELEMENT
1st VALLEY - HOLLOW DAM OF TYPE S' BARTHÉLEMY
2nd VALLEY - HOLLOW DAM OF TYPE BARTHÉLEMY
1st VALLEY - HOLLOW DAM OF TYPE MARCELLO
3rd HOLLOW DAM OF TYPE S' BARTHÉLEMY
2nd VALLEY - HOLLOW DAM OF TYPE MARCELLO
3rd VALLEY - HOLLOW DAM OF TYPE MARCELLO
CROSS-SECTION OF DAM TYPE MARCELLO
CROSS-SECTION OF DAM TYPE St. BARTHÉLEMY
CROSS-SECTION OF MASSIVE DAM
0.45
0.38
0.38
0.38
0.45
0.38
0.42
0.4658
0.5089
0.52
0.00
0.70
22.00
12.00
DEPTH FROM MAX WATER LEVEL
m
%

Fig. 28. Percentage economy in concrete volume between two hollow dams and a solid gravity dam as a function of the height of the structure

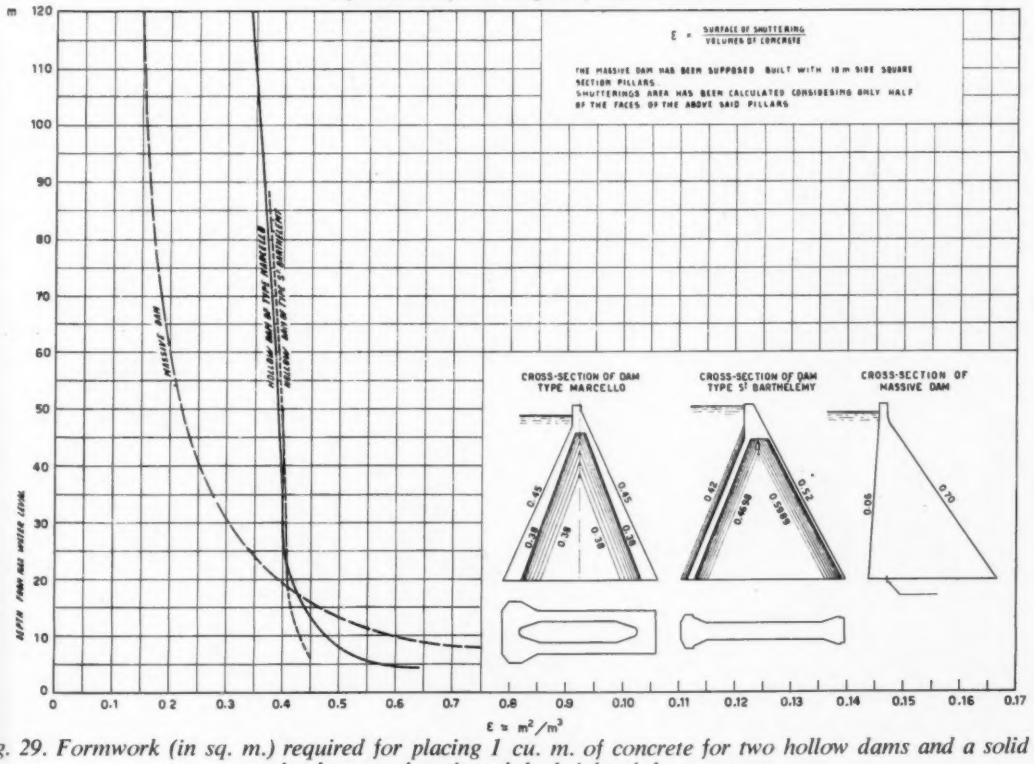


Fig. 29. Formwork (in sq. m.) required for placing 1 cu. m. of concrete for two hollow dams and a solid gravity dam as a function of the height of the structure

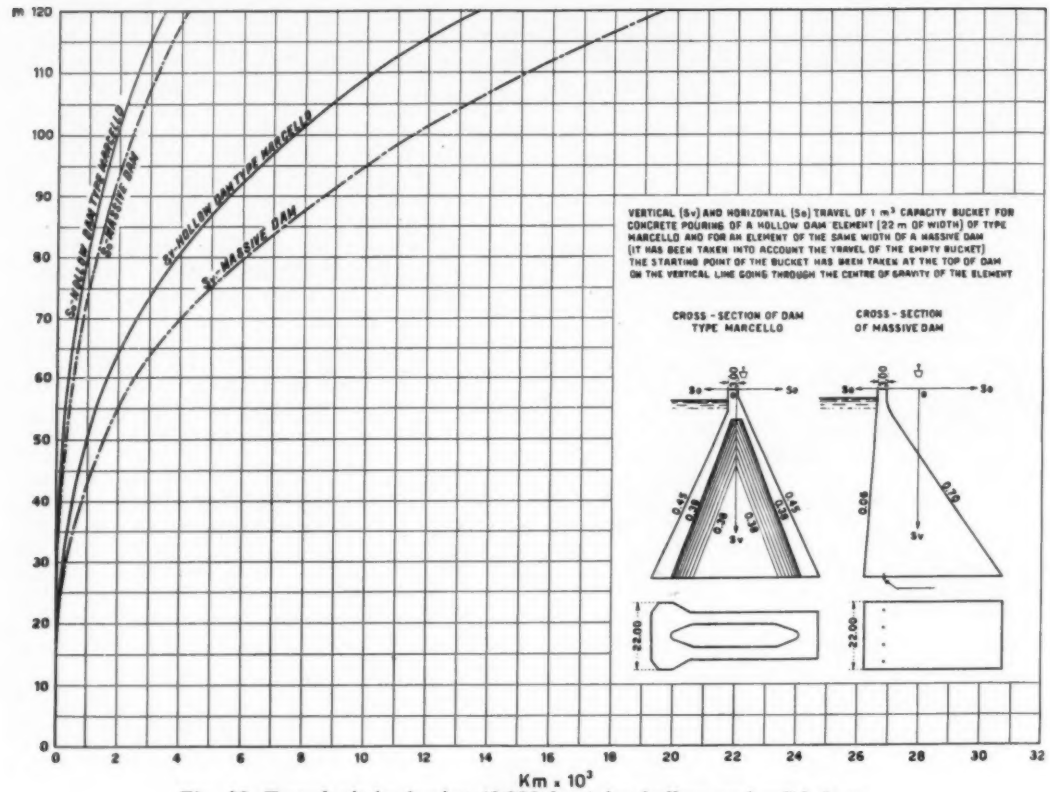

m 120
110
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
Km x 10³
Sv-HOLLOW DAM TYPE MARCELLO
Sv-MASSIVE DAM
Sv-HOLLOW DAM TYPE MARCELLO
Sv-MASSIVE DAM
VERTICAL (Sv) AND HORIZONTAL (So) TRAVEL OF 1 m³ CAPACITY BUCKET FOR CONCRETE POURING OF A HOLLOW DAM ELEMENT (22 m OF WIDTH) OF TYPE MARCELLO AND FOR AN ELEMENT OF THE SAME WIDTH OF A MASSIVE DAM (IT HAS BEEN TAKEN INTO ACCOUNT THE TRAVEL OF THE EMPTY BUCKET) THE STARTING POINT OF THE BUCKET HAS BEEN TAKEN AT THE TOP OF DAM ON THE VERTICAL LINE GOING THROUGH THE CENTRE OF GRAVITY OF THE ELEMENT
CROSS - SECTION OF DAM TYPE MARCELLO
CROSS - SECTION OF MASSIVE DAM
So
Sv
0.45
0.38
0.38
0.45
0.09
0.70
22.00

Fig. 30. Travel of the bucket (1,000 km.) for hollow and solid dams

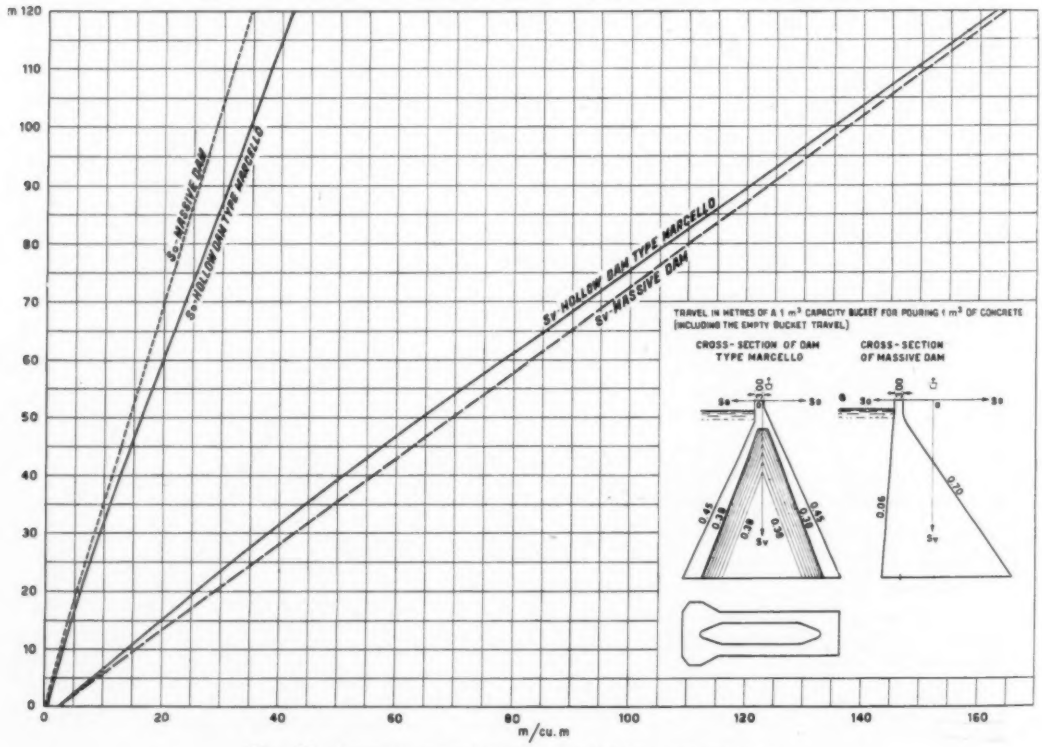


Fig. 31. Average travel of the bucket (m. per cu. m.)

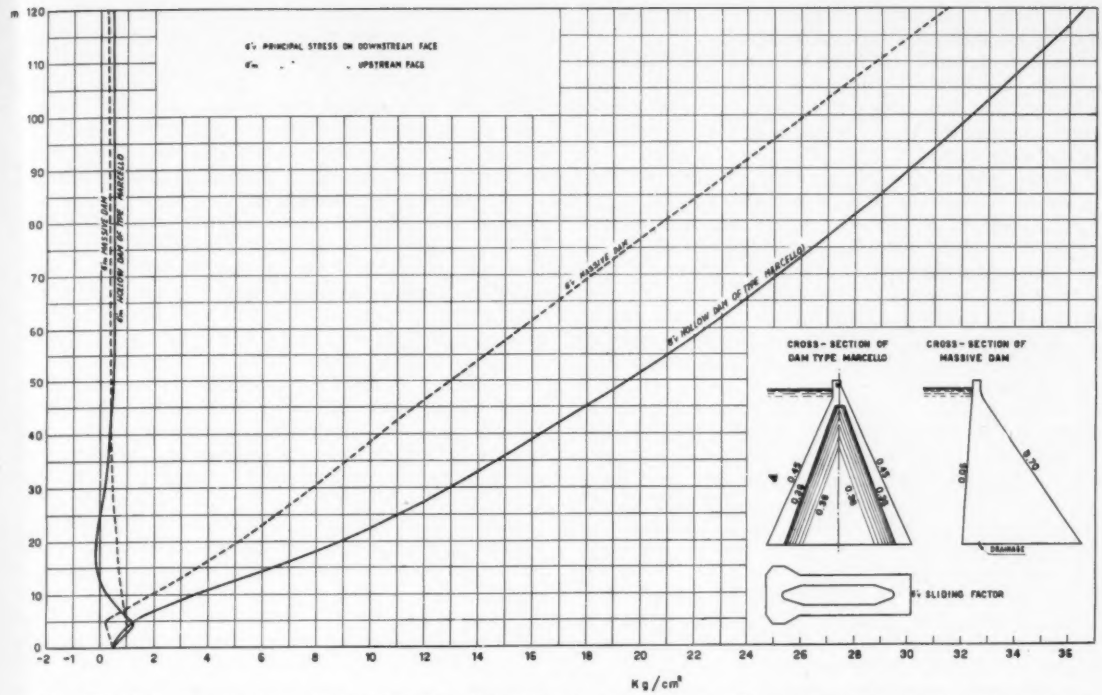


Fig. 32. Main stresses in a dam of the Bau Muggeris type and in a solid gravity dam as a function of the height of the structure

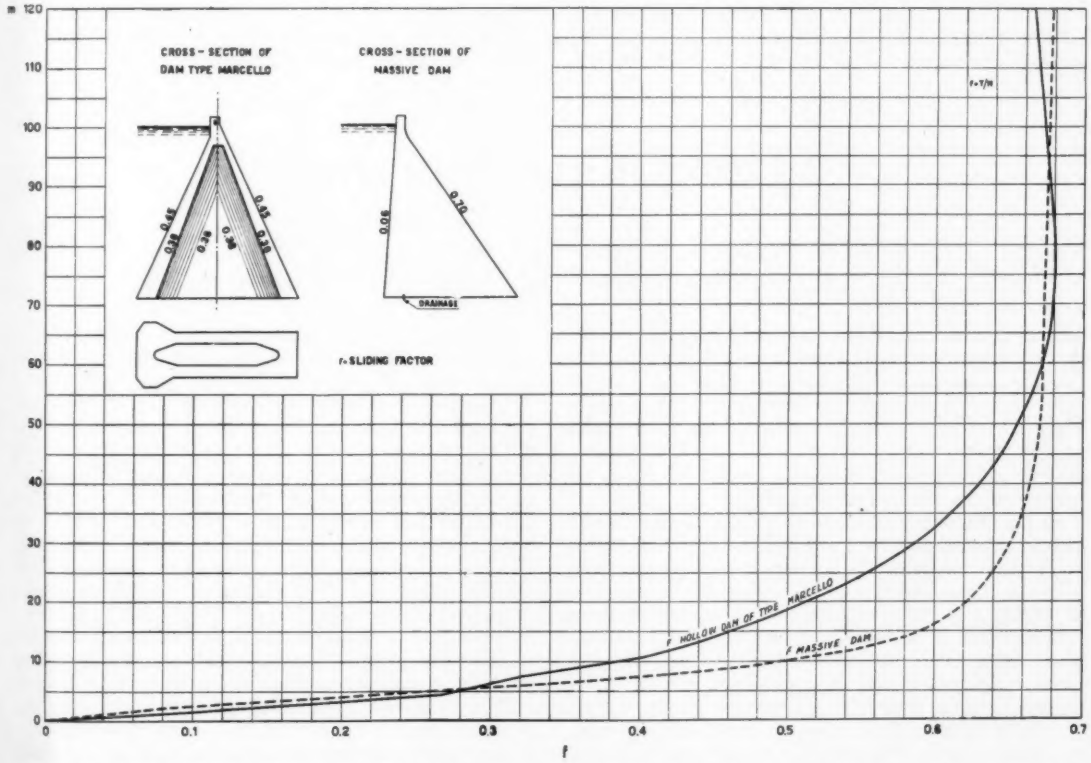


Fig. 33. Vertical/horizontal stress ratio for a dam of the Bau Muggeris type and for a solid gravity dam as a function of the height of the structure

m. of forms corresponds to about 5 to 7 per cent. of the cost of one cu. m. of concrete.

As the increase of formwork necessary for the cellular dam (Bau Muggeris type) in respect of the solid gravity dam is about 0·20 sq. m., the bracing cost increases by 1 to 1·4 per cent. of the unit cost of concrete.

These figures, of course, may change in the different cases in connection with the characteristics of the forms used and the cost of concrete, which, in its turn, depends on local conditions. It may be considered, however, that the above value does not depart from a reasonable average.

These statements, of course, are valid for cellular dams having facings with features requiring plain and uniform forms, as they are for the cellular dam under consideration.

b. We pass now to discuss whether the costs are higher for placing concrete in a cellular dam than they are in a solid dam. We assume the cost of placing to be, as it mostly is, proportional to the mean length of travel from the mixing plant to the dam, placing to be effected by means of Blondins and buckets. Any other system, from our standpoint, may be schematically referred to this one.

We have plotted in Fig. 30 the vertical and horizontal travel curve in metres of movement of a 1 cu. m. bucket to place 1 cu. m. of concrete in the dams under consideration for heights up to 120 m. The cellular dam requires a slightly longer horizontal movement and a shorter vertical travel. If the absolute cost of the two movements is kept into account, the cellular dam shows some advantage.

The diagrams plotted in Fig. 31 show the vertical and horizontal travels of the same 1 cu. m. bucket for the pour of elements of equal width in a cellular and in a solid dam. The advantage of the cellular dam is evident in both movements, and this appears quite justified when the more symmetrical shape of the structure is kept in mind. No greater difficulty is encountered in handling the buckets for the cellular dam, because the dimensions of the different parts of the structure and the absence of scaffolding afford the same easy placement in both types of construction.

c. As regards the cement ratio, it is the author's opinion that the concrete characteristics should be such as to ensure, in addition to stability, a long life of the structure, chiefly in connection with water seepage and climatic variations, and that the mechanical strength of a concrete prepared for a long life is much greater than required from a static standpoint in most of the solid and cellular dams.

On the other hand, the difference between the principal stresses in equally high solid and cellular dams (of the type described here) is not very great, and in any case the values of stresses are in both cases much lower than the strength assured by a long-life concrete (also with a factor of safety of 8 to 10) up to considerable heights of the structures (about 100 m.).

The difference between the principal stresses and the ratios of horizontal to vertical forces is plotted in the diagrams shown in Figs. 32 and 33 respectively.

Concluding, the unit cost of a cellular dam of the type under consideration may be considered as very near to the cost of a solid gravity dam. The only difference is in the higher charge for forms which, as above discussed, may be valued as about 1—2 per cent. of the cost of concrete.

This article was published in Italian in the monthly review *L'Energia Elettrica* No. 6, Vol. XXVIII, 1951, edited in Milan (Italy).

The Djoué Scheme

Brief particulars are given of an interesting hydro-electric project in French Equatorial Africa.

THE enormous superficial area of French Equatorial Africa—equal to six times that of France itself—is a territory in which there exists as great a hydro-electric potential, in relation to size, as anywhere else in the world. The river Congo, as it passes through the territory, has a flow of 1·06 million cusecs (30,000 cu. m. per second) with a peak flow of 2,470 million cusecs (70,000 cu. m. per sec.).

At the moment there are a number of sites under survey, although the total amount of energy potentially available is not likely to be harnessed for very many years to come. At Bouali, 80 kilometres north-west of Bangui, a hydro-electric installation is being planned, and it is understood that it can provide at least 10,000 kW.

The mid-Congo region is the most active in the economic sense, and in order to increase its sources of power hydro-electric sites have been under consideration on the Djoué river which flows into the Congo, and at Oémé and Kouilou on rivers flowing directly into the Atlantic Ocean in that region.

Of these projects, an installation on the Djoué, in the suburbs of Brazzaville, has been under construction for some time and is now nearing completion.

The work on the dam was begun in 1950. It is essentially a mass gravity type of dam, erected on the Djoué river near its junction with the Congo. The water from the dam is taken through an intake tunnel, 825 m. long, passing under the plateau which separates the Djoué and Congo valleys. The dam is 185 m. in length at the crest, 10 m. high and contains two spillways, 6 m. wide, closed by sector gates. It will provide a mean output of 200 cu. m. per sec, with a maximum of 400 cu. m. per sec.

Near the intake point at the power station there is a surge chamber, 10 m. in diameter, the top being 35·9 m. above the level of the tunnel. The tailrace, 180 m. long, discharges direct into the Congo through a backwater.

The power station will ultimately have four units of 10,600 h.p. each, of the vertical Francis type, operating under a head of 27·9 m. and running at

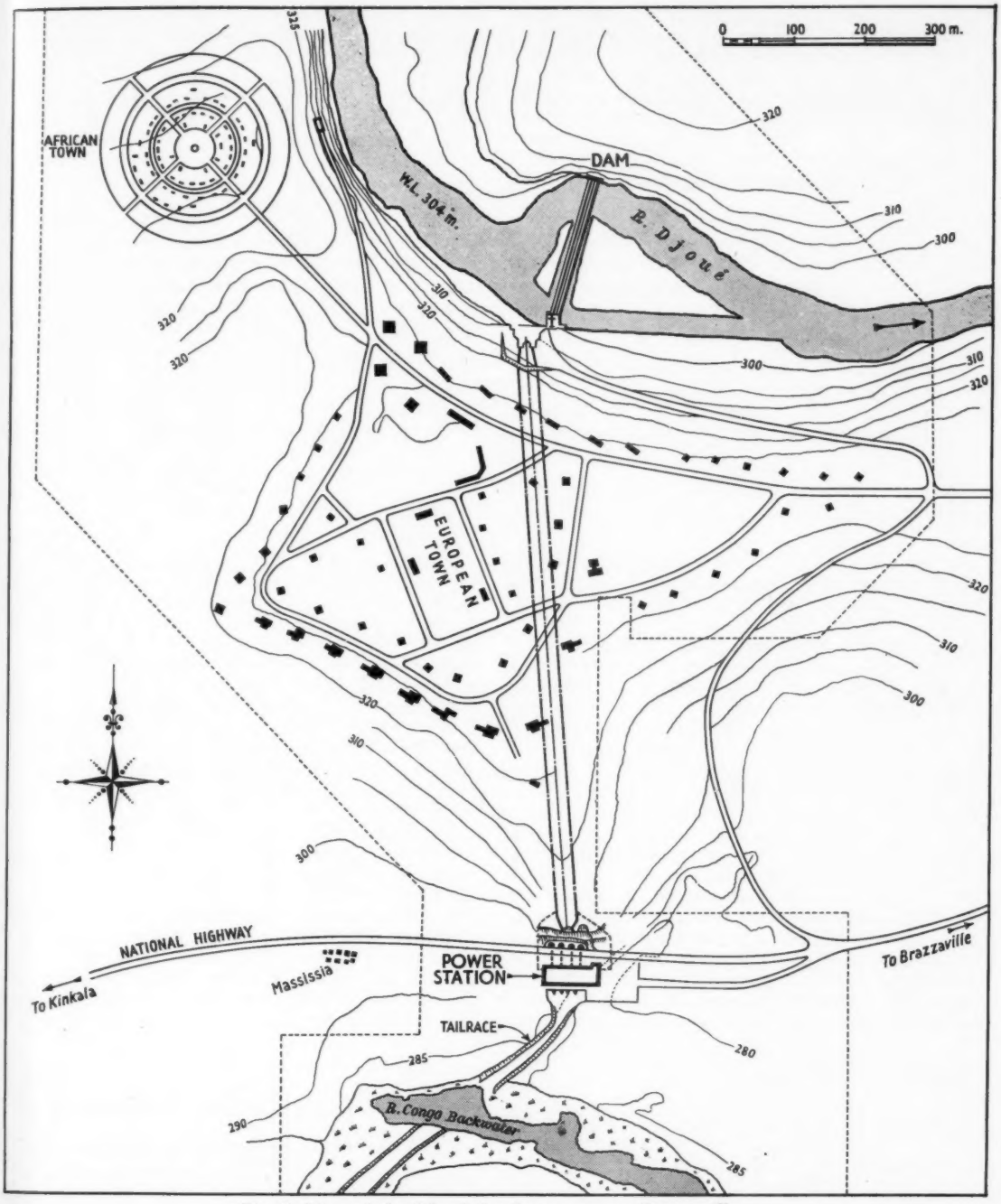


Fig. 1. Map of the Djoué development near Brazzaville

350 r.p.m. These will be coupled to 9,400 kVA alternators, generating at 5·5 kV; and the current will be taken to an outdoor substation where it will be transformed up to 30 kV for transmission to Brazzaville. It is expected that the output of the station will be of the order of 120 million kWh per annum. The initial stage comprises the installation of two units, employing Neyrpic turbines coupled to Cie. Electro-Mechanique alternators. The civil-engineering work was carried out by the Ste. Générale d'Entreprises for an organisation known as the Energie Electrique de l'Afrique Equatoriale Française.

It is expected that in the future the harnessing of other sites will allow of the general distribution of energy in the mining region to the south-west of Brazzaville, and will also permit the electrification of the Congo-Océan Railway, which is an indispensable artery for this part of French Equatorial Africa.

Water-Turbine Governors and the Stability of Hydro-Electric Plant

In this series of articles, the water-turbine governor is considered in relation to control of the electrical transmission network, as well as to regulation of the water supply system including the surge tank. The principles underlying the design and operation of water-turbine governors are reviewed and a typical oil-pressure governor is described in some detail, along with its pressure oil supply. A short general account of the double regulation system for water turbines is then given, and is rounded off by a discussion of the stability of water-turbine governors.

By N. G. DENNIS, M.A., D.I.C., A.M.I.Mech.E., A.M.I.E.E.

PART TWO

WE will now proceed to a consideration of the different types of governor employed for water turbines and discuss their characteristics.

Accelerometer and Temporary-return Motion

Fig. 5 is a simple diagram of a temporary-return motion governor, and Fig. 6 depicts an accelerometer governor. Although the overall behaviour of the two governors is practically identical, the internal behaviour is very different. In each case, there is a distributing valve with a servomotor, and the position of the piston of the distributing valve determines the flow of oil to and away from either side of the servomotor piston as shown in Fig. 7a. By itself the action of the servomotor is to integrate the displacement of the distributing valve piston as a function of time and it is therefore called an integrating servomotor. Another way of expressing this is to say that the distributing valve controls the rate of flow of oil and that the volume of oil corresponds to the position of the servomotor piston. At the same time as the distributing valve supplies oil to one side of the piston, it allows oil to evacute from the other side.

The function of the combination of distributing valve and servomotor is entirely different when a feedback or return motion is taken from the servomotor piston back to the distributing valve piston. This is shown in Fig. 7b where the vertical member is the floating lever which adds the movement of the servomotor to that of the input, and the sum acts on the distributing valve piston. The mechanism then functions to transmit displacements with a very considerable amount of force amplification. This is easily apprehended physically, when it is realised that for any steady position of the mechanism the distributing valve piston must be at dead centre, and that the output is therefore directly proportional to the input as determined by the floating lever, considered as pivoting about the distributing-valve operating link. With the temporary-return-motion governor as shown in Fig. 5, the arrangement is the same with the speed as input and the return motion modified so that it is temporary in action. The temporary-return motion produces an action combining those of Figs. 7a. and 7b. When the orifice of its dashpot is closed, the return motion is rigid, and the servomotor provides a

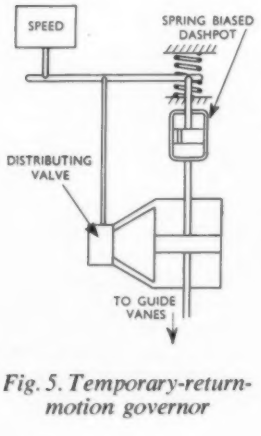


Fig. 5. Temporary-return-motion governor

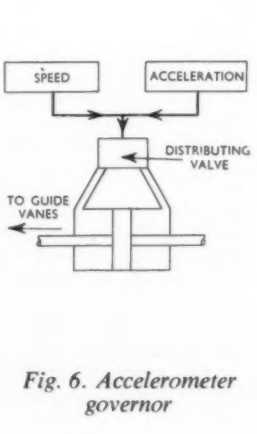
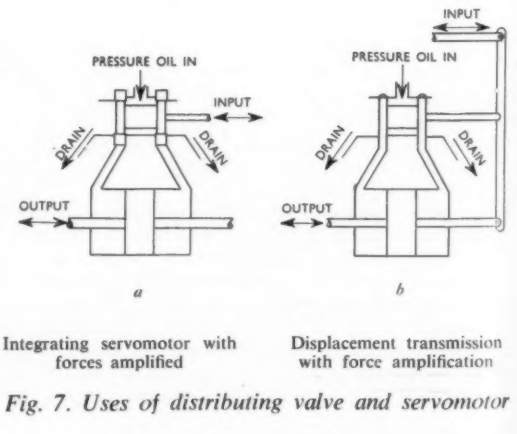


Fig. 6. Accelerometer governor



Integrating servomotor with forces amplified

Displacement transmission with force amplification

Fig. 7. Uses of distributing valve and servomotor

direct transmission of displacement as Fig. 7b. On the other hand, when the orifice is large there is no effective return motion and the servomotor becomes the integrating servomotor of Fig. 7a. Thus, when the orifice forms a partial restriction, combined transmission and integration take place.

In practice, it is found that the distributing-valve piston of the accelerometer soon reaches a big displacement during a change of speed, whereas that of the temporary-return-motion governor moves comparatively little; however, this is counterbalanced by the fact that the servomotor of the accelerometer, for the sake of stability, must have a slow rate of response, whereas the servomotor of the temporary-return-motion governor acts almost instantaneously. The overall behaviour is thus the same, since each governor can be considered as composed of two elements, one slow and the other fast.

As might be expected, the response to internal adjustment, such as that due to the change-of-speed device, is also different. A small permanent-return motion is built into the accelerometer governor to provide the necessary speed-load droop as required for parallel operation; and manipulation of the change of speed device then produces a slow continuous adjustment of the servomotor. However, with a governor which has a large temporary-return motion, the initial movement is as though the temporary-return motion were rigid, and the second stage of the movement occurs when the action of the dashpot predominates to adjust slowly the position of the servomotor.

The two methods of stabilisation have a very similar total effect. The accelerometer governor will be seen to add acceleration and speed changes, integrate the sum, and cause this to act on the guide vanes. The temporary-return-motion governor summates the effects of both speed and the integrated speed through the action of the return-motion dashpot. Therefore, both types of control cause the guide-vane movement to be influenced not only by the deviation of speed, but also by the discrepancy in the angular displacement of the shaft, i.e. integrated-speed deviation. Fig. 8 is a schematic comparison of the two control systems.

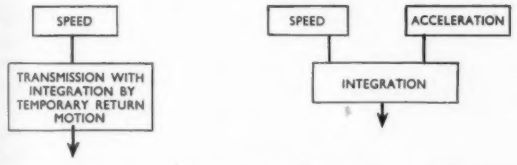


Fig. 8. Comparison of two existing types of governor

The statement that the accelerometer responds immediately to acceleration before any change of speed has taken place, whereas a temporary-return-motion governor operates only after change of speed and, furthermore, is restrained by its return motions is obviously untrue. Many analyses have shown the two types to be very similar in action.

In general, a servo system with derivative stabilisation is less resistant to output disturbances than is a system stabilised by feed-back. The reason is that any disturbance has to travel right round the loop before the distributing valve can take any corrective action. With feed-back stabilisation, corrective action is instigated very directly and effectively across the feed-back. In this specific instance, any friction or backlash in the operating gear of the guide vanes has a worse effect with the accelerometer than with the temporary-return-motion governor. This difference in effect, however, is practically eliminated if the integrating servomotor of the accelerometer is followed by further amplification as in Fig. 7b and does not have to operate directly against stiction; otherwise, integration takes places under adverse conditions, which will cause hunting.

With a temporary-return-motion governor, the rate of action can be made as rapid as desired, since it is controlled by the temporary-return motion itself. This renders adjustment of the governor at site very easy, especially since changes in the stroke of the temporary-return motion itself usually are not needed, and adjustment is required simply of an orifice which controls the characteristic time of the dashpot. Similar adjustments on an accelerometer governor are either more difficult, or they utilise a complicated mechanism, because both the amount of acceleration injected and the rate of response of the integrating servomotor have to be adjusted.

In general, the accelerometer governor is more complicated than the temporary-return-motion governor.

Electric Governor

Hydro-mechanical governors have undergone extensive development in the last half century, and the modern product has a high degree of performance, reliability and cheapness. By comparison with similar electrical governors, a clear and direct physical understanding on the part of maintenance staff is much easier to attain and, at isolated sites, this can be very important.

As experienced with other servo-mechanisms, a more extensive use of electrical circuits on the low-power side of the governor would appear advantageous. Probably the most important practical advantage would be an easier and cheaper method of stabilisation, enabling the essentially high-quality manufacture of the somewhat intricate hydraulic mechanisms to be eliminated. Furthermore, the elements affecting the control of the governor, such as a remote water level, can be easily derived, transmitted and combined.

Viewed in this light, there is perhaps a certain redundancy in the present-day practice of deriving an electric current from the permanent-magnet generator on the shaft of the generating set and then converting this back into the mechanical rotation of the actuator shaft. An alternative would be to rectify this electric current and feed it into a simple direct-current electrical circuit made up of condensers and resistances (Whiteley 1947).

Further information is given by Brodersen and Hedstrom (1950) and Cuenod (1950).

Possible New Types of Governors

It has been mentioned that the present-day conventional design of governor controls the guide vanes by a movement proportional to the error in speed and to the corresponding error in the rotational displacement of the shaft. This is quite satisfactory for the usual hydro-electric power station, but there are large generating stations with special duties where further refinements are needed to improve system regulation.

Possible methods, of course, are very numerous,

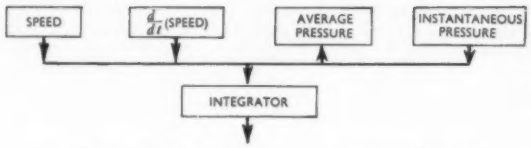
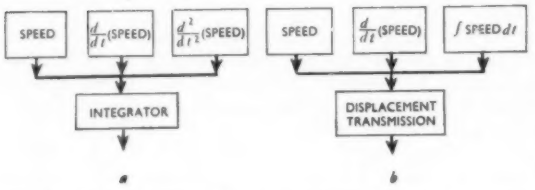


Fig. 9. Stabilisation by pressure feed-back



Addition to accelerometer governor of an element responsive to the rate of acceleration

Simplified form of *a*

Fig. 10. Double derivative stabilisation

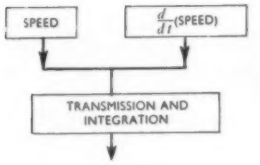


Fig. 11. Combination of two existing types of governor

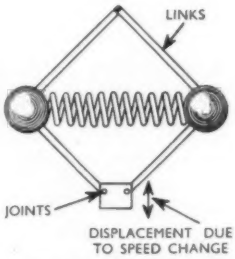


Fig. 12. Typical obsolete pendulum

but three have been described in recent years by Dejou (1948), Almeras (1949) and Daniel (1950). The proposed mechanisms for controlling the guide vanes are shown by Figs. 9, 10 and 11 as block schematic diagrams.

Fig. 9 shows a feed-back from the momentary pressure in the pipeline. Fig. 10a shows the addition to an accelerometer governor of an element responsive to the rate of acceleration. Both these involve serious practical difficulties. Fig. 10b shows a simplification of Fig. 10a which has the same effect. Fig. 11 shows a combination of temporary-return motion and acceleration governors, the temporary-return-motion action being a combination of transmission and integration.

With an isolated turbine, these methods allow the governor to operate nearly six times faster without instability (see Almeras 1949). For a plant performing fast regulation duty on a network, this would allow fast governor operation to be achieved without any decrease in stability.

Actuating Devices in Hydro-Mechanical Governors

Centrifugal Devices. These centrifugal devices act as transmuters from shaft speed to mechanical displacement; in other words, a mechanical displacement is produced which is proportional to the difference between the actual speed and the set speed.

Centrifugal devices on old governors were usually of the type shown in Fig. 12. Although this fundamental design has been improved for present-day use, practice has confined development almost entirely to the two types shown in Figs. 13 and 14. In both of these, effects of backlash and friction are eliminated, and, as a result, the sensitivity of the device has been much increased. The centrifugal device is usually geared up to a comparatively high speed (1,000—1,500 r.p.m.), to reduce inertia and to increase the rate of response. Although not obvious at first sight, the two types shown in Figs. 13 and 14 are very similar. In each case, the configuration of the mass and of its supporting springs varies according to the speed, and the deflection at some point is picked up by a displacement transmission system with amplified forces. This is shown by the rectangle of Fig. 13, and in Fig. 14 by the distorted pilot relay of the type shown in Fig. 17a.

There are three types of speed transmission from the turbine shaft to the centrifugal device. These are given below in order of convenience and of elegance of station layout.

(1) *Electric Drive.* Invariably, a synchronous reaction

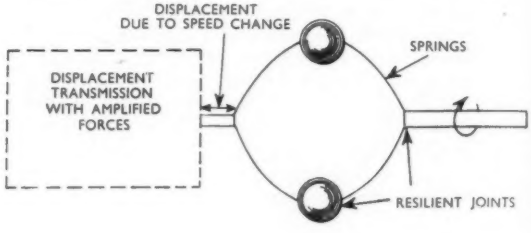


Fig. 13. Modern version of pendulum

motor is used which may be fed with alternating current in one of three ways, given in order of popularity:—

(i) permanent-magnet generator mounted on main shaft;

(ii) special windings in the pilot exciter, if present, which is also equipped with sliprings;

(iii) special transformer at the generator terminals.

Both methods (i) and (ii) are generally approved, but they can be bulky and inconvenient in the comparatively unusual case of a very slow-speed Kaplan turbine. Method (iii) is prone to interference from faults on the electrical supply system. Method (i) gives the quickest follow-up of the centrifugal device when the turbine is being started. In all methods, time lag

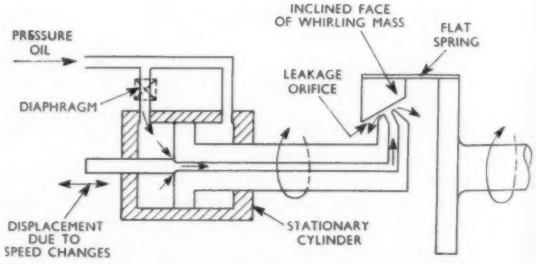


Fig. 14. Modern pendulum with incorporated displacement transmission

of transmission must be negligible; otherwise, hunting will result.

(2) *Mechanical Drive.* Mechanical drive is very reliable. Undue rigidity of transmission has occasionally given trouble with accelerometer governors when comparatively high-frequency oscillations of the turbine shaft, from electrical or hydraulic causes, have induced hunting. On sudden changes of load, shaft oscillations due to pole swinging take place in the generator and that these are damped considerably by the use of amortisseur windings.

(3) *Friction Drive.* Friction drive is more popular in some countries than in others. Certainly it is cheaper, but it is prone to jerky running unless carefully fitted. Jointless silk belts have been used, but necessitate overhung pulleys. In the case of belt drive, devices must be added which in the event of failure, shut down the turbine, either by an underspeed trip, or by a tension-sensitive device on the governor.

Addition and Subtraction Hydraulically and Mechanically

The media used in hydro-mechanical governors are, of course, either hydraulic or mechanical. The two most useful methods for the mechanical summation of displacements are shown in Fig. 15. One of these uses a floating lever whereas the other employs springs arranged in parallel. As shown in the figure, the displacements x_1 and x_2 can be summated as required. The method of parallel springs probably is less known than that of the floating lever. Similar methods can be employed to add or subtract angular displacements. When linear and angular displacements have to be added together, screw threads become very useful.

The floating lever has two degrees of freedom and it can add two quantities together as shown in the figure. A floating three-dimensional body can theoretically summate six quantities, but a practical working arrangement to effect this would be rather difficult. The parallel-springs method is often used where more than two displacements are to be summated.

A simple piston or bellows arrangement is shown in Fig. 16, which enables any number of hydraulic pressures to be added together.

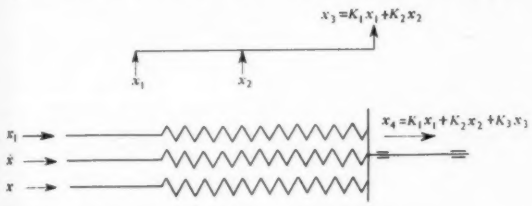
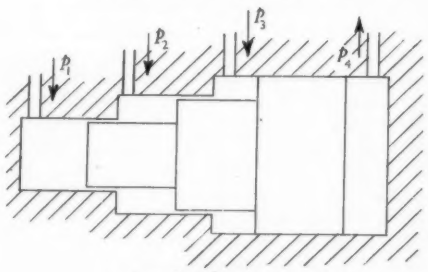


Fig. 15. Addition of displacements



$$p_4 = p_1 K_1 + p_2 K_2 + p_3 K$$

Fig. 16. Addition of pressures

Hydraulic Pilot Relays

Fig. 17 shows three types of pilot relay in common use. The output movement follows the input movement exactly, and at the same time the operating force available is greatly increased. It is essentially a simple integral form of servomotor (usually single acting) and distributing valve with rigid feedback. The relays in Fig. 17 are easily understood; in each case the hydraulic forces on the two sides of the piston balance under steady-state conditions. The pressure on the side of the piston with the larger area has, therefore, to be less than the full pressure on the other side; this reduction of pressure is effected by placing a diaphragm at the entrance and some sort of controlling restriction at the exit. The controlling restriction can be either a choked nozzle or a steering edge similar to a distributing valve. This controlling restriction is arranged between the input and output movements, and it causes the output movement of the piston to follow the input movement of the spindle. Thus, the pilot relay provides a 1/1 displacement with great amplification of control force, and in consequence a great reduction in error due to extraneous forces, such as friction, on the value of the displacement.

Often, a pilot relay is built directly on to the end of the distributing valve that follows it in the control sequence.

Divided Pilot Relay

A typical relay of this type is shown in Fig. 18. It can be considered as half way between the pilot relay and a distributing valve plus a servomotor as in Fig. 7b. In addition to the force amplification provided by the pilot relay, this mechanism can amplify the stroke. Thus the output may be several times greater than the input though still proportional to it. The return motion from a single-acting servomotor acts by means of a simple linkage to move the sleeve of the control valve.

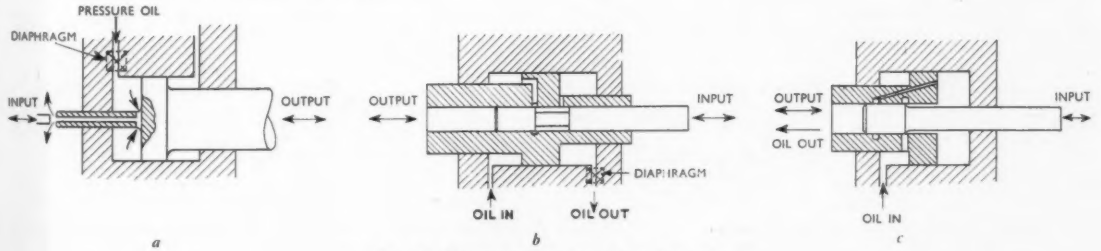


Fig. 17. Types of hydraulic pilot relay

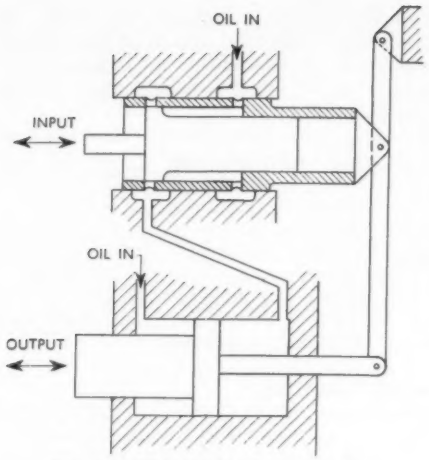


Fig. 18. Divided hydraulic relay

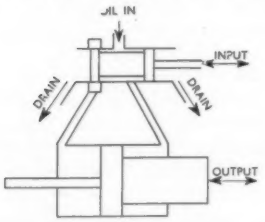


Fig. 19. Single-acting servomotor

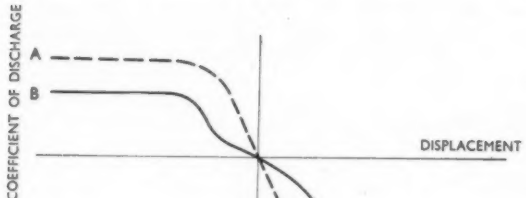


Fig. 20. Characteristics of distribution valve

Distributing Valves and Servomotors

A simple distributing valve for a double-acting servomotor is shown in Fig. 7a, whereas Fig. 18 shows a single-acting arrangement where the smaller side of the piston is always under the same oil pressure (or spring loading). Where very heavy operating forces are required, double-acting servomotors are used, because, for the same dimensions of cylinder and the same available oil pressure, the force available is double that of the single-acting arrangement and is equal to the oil pressure acting on the whole piston area.

Typical flow-displacement characteristics of the distributing valve are shown in Fig. 20. Curve A is a simple characteristic where it is seen that the flow is proportional to the displacement of the valve while this is small. However, for large displacements, saturation occurs where the flow is no longer controlled by the displacement of the piston but by the loss of pressure elsewhere in the circuit, usually at an orifice. For small displacements, the characteristic is determined by the area of the ports uncovered by the valve piston during its movement. If desired, a more complicated characteristic such as curve B can be obtained by varying the periphery uncovered by the valve according to the stroke. In the course of the initial design of the distributing valve, the characteristic of the discharge coefficient against displacement determines the diameter and the stroke.

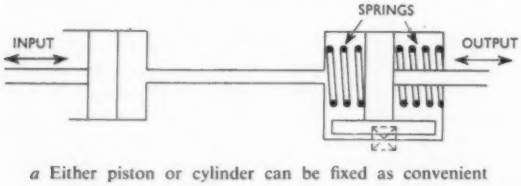
It is often found convenient to mount a pilot nozzle on the end of the distributing-valve piston. When the valve is passing a large flow of oil, the appreciable hydrodynamic out-of-balance forces are held by the piston of the pilot nozzle and thus a very light input movement can be used. Also, a pressure-sensitive control is effected by adding a piston spring element to one end of the valve. Combinations of the above devices have led to many ingenious designs.

In general, there are two ways of overcoming the bad effect of friction on the movement of a distributing-valve piston. The first is by rotating the distributing-valve piston relative to the body of the valve. There is then no static friction and only a slight dynamic friction which is proportional to the speed of the axial movement.

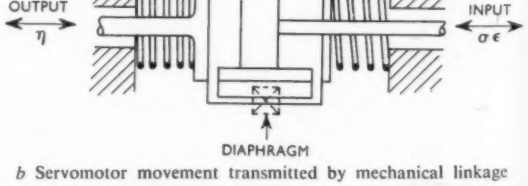
The second method of overcoming friction is to superimpose a dither on the control system. In water-turbine governors, care must be taken to localize this dither and to ensure that it does not reach the main servomotors; otherwise there is danger of hunting in conjunction with water-hammer in the main conduits, and of excessive wear on the turbine regulating gear.

The amount of lap allowed in a distributing valve depends on its function. In this connection, there are the opposed requirements of minimum leakage and maximum sensitivity. A simple positive overlap will give minimum leakage but a small dead band of control. The latter can be avoided by the use of a suitable slight negative lap, or by suitable grooving of the steering edges, which is the equivalent.

There is an optimum size of servomotor and distributing valve for economic operation under given conditions of resisting force, when a certain load has to be moved a specified distance in a given time. Any different size of servomotor would require an exces-



a Either piston or cylinder can be fixed as convenient



b Servomotor movement transmitted by mechanical linkage

Fig. 21. Temporary transient transmission

sively large distributing valve. The reason for this is that the pressure which forces the oil through the distributing valve is the difference between the supply pressure and the resisting back pressure created by the load. If the servomotor is too small, the resisting back pressure becomes too large and thus the distributing valve has to be very big in order to pass the required amount of oil. On the other hand, if the servomotor is too large, the extra flow of oil diminishes the effect of the greater pressure across the distributing valve and necessitates an unduly large one. An economic compromise between these two tendencies has to be reached, having due regard for adequate margin to ensure operation.

Temporary-Return-Motion System

The usual mechanism for the temporary-return-motion system is a dashpot-spring arrangement as shown in Fig. 21. This acts directly on the combination element of the governor. In the form illustrated in Fig. 21a, hydraulic transmission is used and the input piston is fixed rigidly to the main servomotor piston. This input piston acts as the plunger and is connected by a pipeline to a spring-loaded piston fitted with a bypass orifice as shown in the diagram. With the form shown in Fig. 21b, a mechanical linkage transmits the movement of the servomotor to the mechanism.

The rigidity of the transmission is determined by the effective size of the dashpot orifice. This rigidity is arranged to vary as a function of the displacement of the dashpot by cutting special orifices in the walls of the dashpot piston or cylinder which are opened or closed according to the relative position of the two. In order to secure stability for small oscillations, the rigidity is usually arranged to be comparatively high when the dashpot piston is near its position of rest; this rigidity is decreased for larger movements of the mechanism, in order to reduce the restraining action on the movement of the governor which otherwise would cause large changes of speed during major load variations. Similar arrangements are made for accelerometer governors.

Limit-of-Opening Device

The principle of this device is to prevent the governor from increasing the turbine power above a desired value, and is shown in Fig. 22. In the diagram it is shown as a purely mechanical linkage which prevents the distributing valve from admitting oil to the servomotor once it has reached its prescribed extent of stroke.

A second and somewhat similar method is to provide for an exhaust valve to be opened by the servomotor piston at any desired position in its stroke. This exhaust valve releases pressure from the opening side of the servomotor piston and thus prevents further opening.

Acceleration-Sensitive Mechanism

A well-known type is shown in Fig. 23. Here a mass is mounted by springs on the shaft, and relative movement between the mass and the shaft takes place when the shaft is subjected to angular acceleration. A specially prepared surface on the mass operates a pilot relay in a fashion illustrated in Fig. 14. In fact, the mechanism is similar to Fig. 14, but the mass and springs are arranged in a transverse instead of a radial

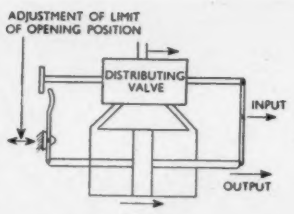


Fig. 22. Limit-of-opening device. Arrows show movement when opening

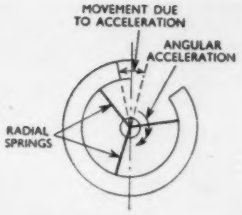


Fig. 23. Transmuter from acceleration

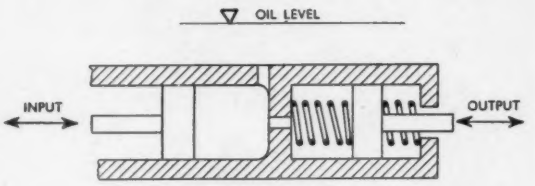


Fig. 24. Hydraulic phase-advance mechanism

direction so as to be sensitive to acceleration and not velocity. Another type measures the change in pressure in a spiral pipe filled with mercury or in a viscous screw-type oil pump. Yet another type uses the hydraulic phase-advance mechanism shown in Fig. 24. Here the measured angular velocity forms the input, and the output motion from the mechanism is to some extent proportional to the acceleration.

ACKNOWLEDGMENT. The illustrations accompanying this instalment are reproduced from the author's paper "Water Turbine Governors" presented to the Institution of Mechanical Engineers on November 7, 1952. Much of the information contained in this series of articles is also repeated from that paper.

(To be continued)

A New Joint Seal. In connection with our description of the Harza Labyrinth Waterstop on page 37 of our January issue, Water Seals, Inc., 9 S. Clinton Street, Chicago 6, Illinois, would like it to be known that patents have been applied for in all major industrial countries of the world. Patents have also been applied for on the various modifications of the waterstop or joint seal.

A Study of Future Power Transmission for the West. —The Bureau of Reclamation of the United States Department of the Interior has published a brochure under the above title drawing attention to the gigantic increase in power requirements that is to be expected during the next 25 years in the western states. A 500 kV grid is envisaged which would interlink hydroelectric plants with thermal stations situated in the coalfields.

Kue-Ken Crushers. Sir W. G. Armstrong Whitworth & Co. (Ironfounders) Ltd. have issued a pamphlet (List No. F 122) describing their Kue-Ken jaw and gyratory crushers. Technical particulars are given and tables are reproduced to indicate capacities, size of feed opening, horsepower required, weight, dimensions, etc. The standard capacity rating table contains a demarcation line to indicate what is good crushing practice with a reasonable ratio of reduction.

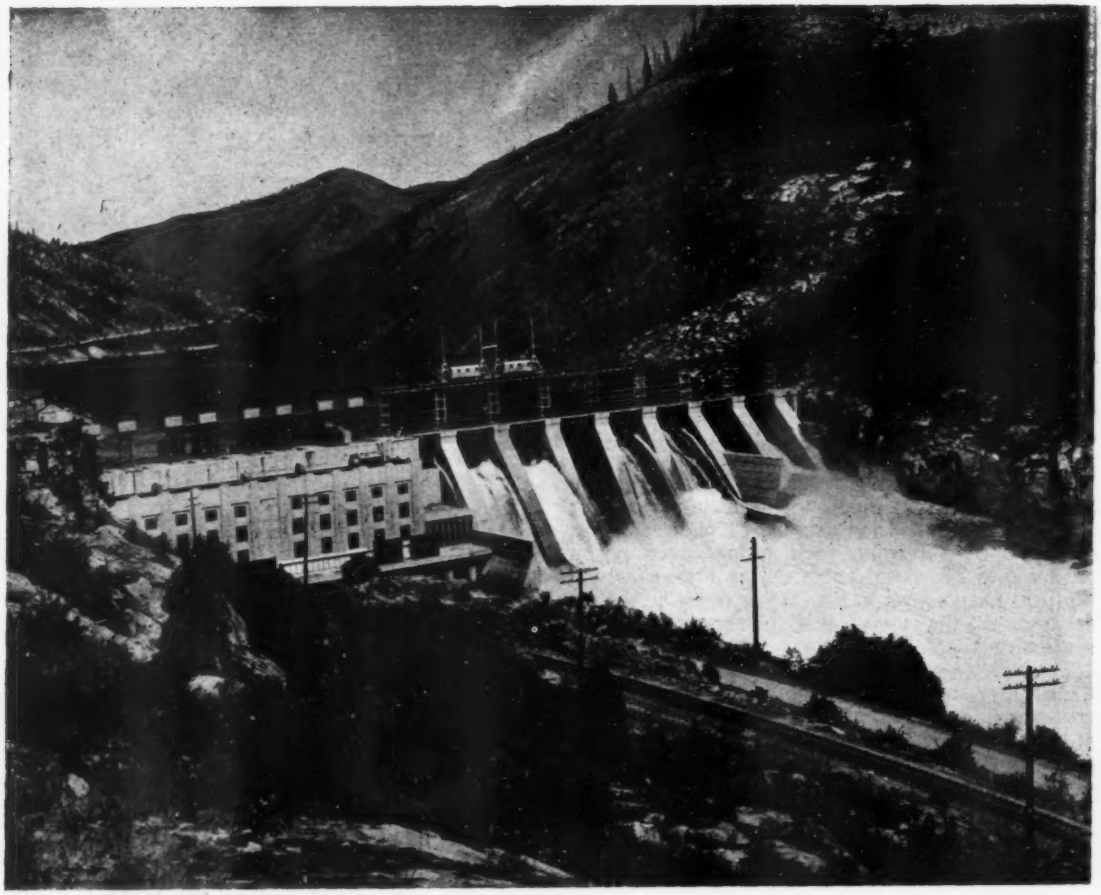


Fig. 1. Brilliant dam and 140,000 h.p. station on the Kootenay River, British Columbia, one of five built by Consolidated Mining and Smelting Company

Hydro-Electric Progress in Canada, 1952

The following review for the year 1952, prepared under the authority of the Hon. Robert H. Winters, Minister of Resources and Development, presents the results of a regular annual survey which is conducted by the Water Resources Division, Department of Resources and Development of the Canadian Government.

A NEW record was established in 1952 in the total capacity of new hydro-electric generating units completed during the year, although not in the net increase in the total of installed capacity of hydraulic plants in Canada. The record total of 1,064,600 h.p. of new hydraulic turbine capacity was brought into operation, but allowing for dismantling of old plants and list adjustments, the net increase is reduced to 961,726 h.p. However, the latter figure is only slightly below the previous record of 988,675 h.p. which was set in 1943 when the huge Shipshaw plant of the Aluminium Company of Canada was completed on the Saguenay River. In 1952, new capacity was more evenly distributed across the country, although the greater portion was located in the Province of Quebec. The new projects which have been undertaken in rather remote regions serve to enhance the potential value of other undeveloped sites which only recently appeared to be located so distantly from centres of population as to be of little economic importance; also the continuing improvement in the technique of long-distance transmission is reflected in proposed transmission lines. The total of installed capacity of water-power plants in Canada is now

Fig. 2. Aerial view of Kemano camp for the Aluminium Company of Canada's Kitimat project, British Columbia

listed at 14,304,230 h.p. which represents only 22 per cent. of known resources. New plants and extensions which are scheduled for operation in 1953 total 860,000 h.p., while other developments which are under preliminary construction, or are definitely planned for later years, exceed 2,000,000 h.p.

In addition to water-power development, a number of thermal units of large capacity were brought into operation and others are under construction. Although the production of the electrical energy to meet Canada's expanding industrial and domestic consumption continues to be largely from hydraulic sources, thermal power capacity is also increasing and becoming a more important factor in the field of power production. Supplemented by the output of new hydraulic and steam plants, total production of electrical power was at a rate of approximately eight per cent. above 1951. In the country as a whole, power-production facilities were sufficient to meet the present demand but little reserve capacity was available.

In the field of power distribution, construction was also very active. New main transmission lines were completed or were under construction in many sections of the country, new transformer and substations were built, and secondary lines were extended. Good progress in rural electrification was achieved, particularly in Ontario, Quebec, and Manitoba.

A review of the year's activities in central-station construction, and in distribution facilities, in each province, is given below.

British Columbia

Two new developments were completed in 1952 and construction was active on other extensions and major new projects.

The British Columbia Electric Co. Ltd. completed its power house at Wahleach Lake, about 15 miles east of Chilliwack, with operation of the single unit of 82,000 h.p. at 2,000 ft. head beginning in December. However, during this winter, output will be limited to run-of-river capacity as completion of the storage dam was delayed by forest closure due to fire hazard in the summer of 1952. The company has placed an order for the fourth unit of 62,000 h.p. to be installed in its Bridge River plant for 1954 operation; preliminary work has been undertaken to raise the level of the La Joie dam to provide increased storage. The expansion was continued of the company's transmission and distribution systems, with the completion of a 230 kV line from Wahleach to Vancouver and of 60 kV lines from Bridge River to Lillooet and Chilliwack to Hope.

The British Columbia Power Commission brought

into operation its two-unit 4,000 h.p. Clowhom Falls plant which is located near the mouth of the Clowhom River at the head of Salmon Arm and which is designed for an ultimate capacity of 12,000 h.p. In its John Hart plant on the Campbell River, the Commission has installation under way on two additional units each of 28,000 h.p., with operation scheduled for early 1953, which will bring total capacity up to 168,000 h.p. A 132 kV line from Campbell River to Duncan, with terminal facilities including two 20,000 kVA transformers, has been completed. Surveys and investigations were made covering proposed small hydro-electric developments on the Kokish River on Vancouver Island and on the Spillimacheen River near Golden.

The Aluminium Company of Canada made good progress on its great Nechako-Kitimat development and work was well up to schedule for anticipated 1954 initial operation. The Kenney Dam on the Nechako River at Grand Canyon has been practically completed; the diversion tunnel was closed in October and storage of water has begun, with the expectation of a rise of 140 ft. in water level behind the dam by December 31, 1952. Driving of the 10-mile 25 ft. diameter tunnel from Tahtsa Lake to Kemano was well under way with four miles completed in 1952. Drilling of the two penstocks from the tunnel to the power house is well advanced, and the excavation is half completed for the underground cavity to house the three units of the first stage. Construction is proceeding satisfactorily on the 50-mile transmission line to Kitimat, with clearing and placing of tower footings about half completed and one-fifth of the towers in place. No definite plans have been made for expansion beyond the present programme of 420,000 h.p. in three units to be completed in 1954, although the ultimate capacity of the development is estimated at more than 2,000,000 h.p.

Fig. 3. Road building in difficult country at Kitimat

The Consolidated Mining and Smelting Company Limited made rapid progress on its Waneta development on the Pend d'Oreille River and it is now expected that the plant will be brought into service in 1953. Initial capacity will comprise two turbines, each of 105,000 h.p. driving a 90,000 kVA generator; the ultimate capacity is 420,000 h.p. Power will be delivered to Trail over three 60 kV lines to be constructed in 1953. The company expected to complete by the end of 1952 its 82-mile 170 kV line from South Slocan to Kimberley, including a two-mile span across Kootenay Lake.

Yukon Territory

The Northwest Territories Power Commission in November brought into operation its Mayo River development near Mayo Landing, about 215 air miles north of Whitehorse. The present plant consists of one turbine of 3,000 h.p. under average head of 118 ft. driving a 3,000 kVA generator, but provision has been made for a second similar unit. The project includes a main earth-fill dam 115 ft. in height and of 360 ft. length on the Mayo River and a rock-filled timber-crib storage dam at the outlet of Mayo Lake. Power is transmitted to the Galena and Keno Hill mining areas over a 33-mile 69 kV line. Service is also supplied to the nearby village of Mayo Landing.

The Yukon Hydro Company Limited is planning to increase the capacity of its Porter Creek plant, near Whitehorse, from 500 h.p. to 1,440 h.p. An order has been placed for a 940 h.p. turbine and 875 kVA generator for 1953 delivery.

Alberta

No new hydro-electric plants were brought into operation but Calgary Power Limited began preliminary construction on the Bearspaw development, on the Bow River just west of Calgary, to consist of one unit of 22,000 h.p. for 1955 operation. The company also is undertaking for 1954 operation the installation in its Ghost plant on the Bow River of a fourth unit of 30,000 h.p. driving a 23,500 kVA generator. During 1952, the company continued the expansion of its transmission system, including the building of 95 miles of a line at 132 kV from Medi-

cine Hat to Calgary which will be completed in 1953; 19 miles of 66 kV line and 168 miles of 13 to 33 kV also were completed. During the year, service was given to 3,500 farms and the total now on line is 14,000 farms.

Manitoba

The Manitoba Hydro-Electric Board completed its 114,000 h.p. Pine Falls development on the lower Winnipeg River, four units having been put in service in 1952. The plant comprises six units each of 19,000 h.p. under 39 ft. head, two of which were brought into operation in 1951. Generators are rated at 15,500 kVA. Power is delivered to Parkdale substation in Winnipeg over a 115 kV line which was completed in 1952. The Board has begun preliminary construction of the McArthur Falls development on the Winnipeg River at the outlet of Lac du Bonnet; camps and access roads have been built, cofferdam construction is under way, and contracts have been awarded for the hydraulic and electrical equipment. The plant will have a capacity of 80,000 h.p. in eight units each of 10,000 h.p.; generators are rated at 8,500 kVA. Operation is scheduled for 1955.

The Winnipeg Electric Company completed in September 1952 the installation of the sixth and final unit of 37,500 h.p. in its Seven Sisters plant on the Winnipeg River. The plant has a total turbine capacity of 225,000 h.p. under 66 ft. head and a generator capacity of 195,000 kVA. The Pinawa channel has been blocked off and sealed against leakage.

Sherritt-Gordon Mines Limited brought into operation its 7,000 h.p. plant on the Laurie River and power is now being supplied to the Lynn Lake mining field. The development includes a storage dam on Eager Lake. Preparatory to a second development, work will begin in 1953 on the construction of a storage dam on the Loon River and a diversion canal to the Laurie River.

The Manitoba Power Commission continued its programme of rural electrification and extended service to 5,000 farms and to 33 towns and villages. A total of 34,000 farms are now on line. New transmission lines include 60 miles at 115 kV, 127 miles at 66 kV, and 128 miles at lower voltage; also about 200 miles of line were converted to higher voltage. Substation capacity was increased by 39,000 kVA.

Ontario

The Hydro-Electric Power Commission of Ontario continued construction during 1952 on two hydro-electric and two steam-electric projects, each of major proportions; also important additions were made to its transmission and distribution systems.

The first unit at the Otto Holden generating station, which is located on the Ottawa River above Mattawa, was placed in operation on January 10, 1952, and the second on January 22. The next five units were placed in service in the months of March, April, July, September, and November, respectively. The eighth and final unit is expected to be placed in service early in 1953. Construction is essentially complete except for those features incidental to the installation of unit No. 8, and clean-up of the project. The eight units of this plant will have a total installed turbine capacity of 264,000 h.p., each unit being rated at 33,000 h.p.

The Sir Adam Beck-Niagara generating station No. 2 covers a greater utilisation of the power resources of the Niagara River, as allowed by the Niagara Diversion Treaty of 1950. Construction work was begun in 1951 on the first stage comprising seven

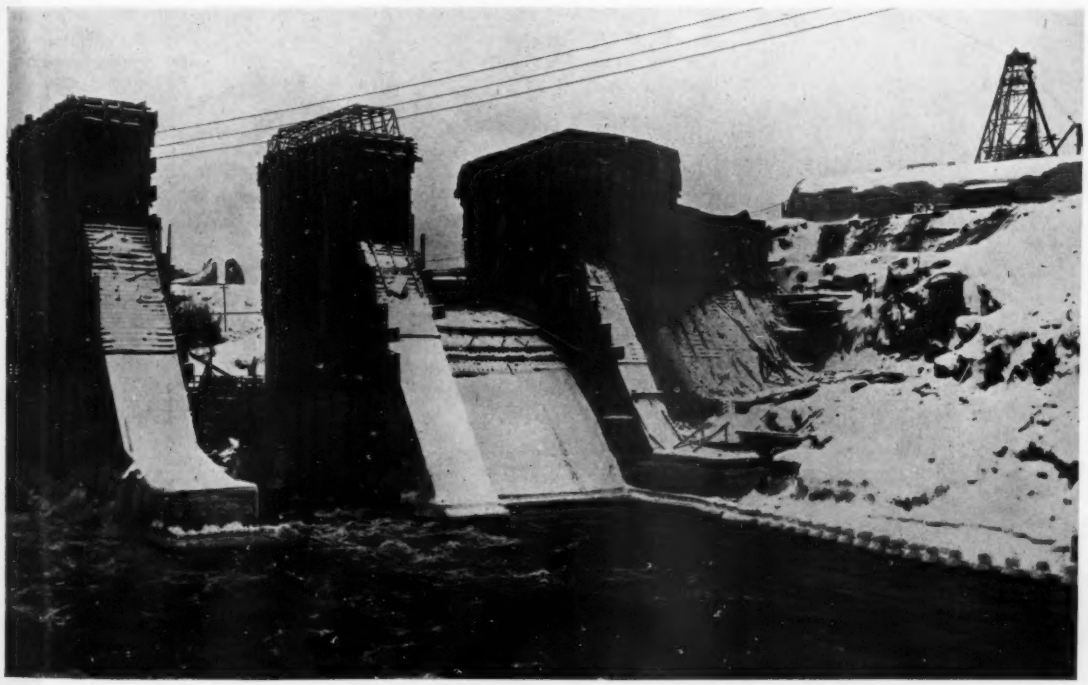


Fig. 4. Part of the Chute-du-Diable dam under construction for the Aluminium Company of Canada

units served by tunnel No. 1. In August 1952, authority was granted for the installation of five additional generating units, together with the second tunnel, intake structure, and other related facilities. Construction progress is well advanced on the many phases of the project. At the intake, the excavation for the gathering-tube associated with tunnel No. 1 is well advanced, while the cofferdam for the second gathering-tube has been placed. Tunnel No. 1 has been about one-third excavated, and excavation for tunnel No. 2 is under way. For the canal and headworks' section (for the complete project) most of the earth excavation and more than half of the rock excavation has been completed, and the headworks concrete placing is well advanced. At the power house (for the 12 units), about two-thirds of the penstock excavation has been completed and the major portion of rock has been removed for the power house. Concrete placing for the power house and for the penstock envelope and saddles is also well advanced. The 12-unit installation, totalling 1,260,000 h.p., is planned for initial operation in 1954, and to be completed in 1956.

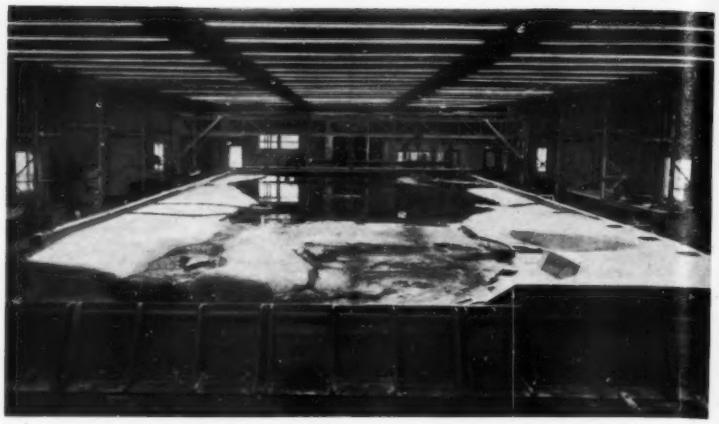


Fig. 5. Scale model of the Niagara Falls development

The third unit at Pine Portage, Nipigon River, was authorised early this year. This unit will be rated at 45,000 h.p. and is planned for operation in the autumn of 1954. The major equipment has been ordered, and engineering and design has been started.

The two important thermal stations are the J. Clark Keith and Richard L. Hearn stations at Windsor and Toronto respectively, and the initial stages of both projects are now in operation.

During the year the Commission extended its transmission and rural line facilities by the approximate amounts indicated in the following tabulation:

230 kV lines	... circuit miles	...	82
115 kV lines	... circuit miles	...	104
44 kV and lower	circuit miles	...	410
Rural lines	... circuit miles	...	1950

The total number of farm services was expected to be approximately 129,000 by the end of 1952.

In addition to the activities of the Commission, the Great Lakes Power Company is constructing a 20,000 h.p. plant at Scott Falls on the Michipicoten River, with operation anticipated early in 1953. The plant contains two units each of 10,000 h.p. under 75 ft. head and generators are rated at 8,500 kVA. Also preliminary construction has begun on a two-unit 15,000 h.p. development upstream at McPhail Falls where the head is 48 feet; initial operation is scheduled for late 1954.

Quebec

The Province of Quebec, which is rich in water-power resources, continued to lead in development by bringing into operation a total of 597,000 h.p. and with other major plant expansions and new projects under construction.

In its Beauharnois No. 2 power house on the St. Lawrence River, the Quebec Hydro-Electric Commission increased capacity by 222,000 h.p. in four new units, two of 55,000 h.p. and two of 56,000 h.p. The capacity of the No. 2 power house is now 555,000 h.p., while that of the entire development is 1,297,000 h.p. which will be increased to its ultimate of 1,408,000 h.p. by the end of 1953 by the addition of the final two units. Dredging operations in the intake canal are being continued and will be accelerated by the use of an additional powerful dredge to be available in the spring of 1953. Construction of the new plant at Rapid II on the upper Ottawa River is proceeding according to schedule, and two units each of 16,000 h.p. are expected to be in operation by December 1953; the ultimate capacity of this plant will be 64,000 h.p. At the Rapid VII plant, one 15,000 kVA generator has been converted from 25 to 60 cycles. On the North Shore of the lower St. Lawrence River, preliminary field work is under way for the construction of a large hydro development on the Bersimis River, some 62 miles above the mouth. It is planned to develop approximately 1,000,000 h.p. at this site, and it is expected that 300,000 h.p. will be in service by the latter part of 1956. In the field of power distribution, the Commission completed a 25-mile high-voltage transmission line between Cadillac in Northwestern Quebec and the generating plant under construction at Rapid II; an 18-mile line between Rapid VII and Rapid II, and a 31-mile high-voltage transmission line linking Beauharnois with Montreal North, will be completed in 1953. The Commission is planning the laying in 1953 of a 31½-mile submarine cable on the bed of the St. Lawrence River from the Manicouagan Peninsula on the North Shore across to Les Boules on the South Shore; also a beginning on the construction of other transmission lines from the Manicouagan and Bersimis plants, including one to Montreal. A transmission line from the Ottawa River plants, approximately 146 miles in length, is contemplated to serve the Lake Chibougamau mining district. New substations have been completed, enlarged, or are in the course of erection in Montreal and Northwestern Quebec.

The Aluminium Company of Canada expected to complete its Chute-du-Diable development on the Peribonka River by the end of 1952. At the end of October, four units were in operation, and it was

anticipated that the fifth and final unit would be ready about the middle of December. The total turbine capacity of the plant will then be 275,000 h.p. Power from this station is carried over a new double-circuit 154 kV tower line to the switching station located at Isle Maligne, a distance of approximately 16 miles. The Chute-a-la-Savanne plant, also under construction by the company, is located about 13 miles downstream from Chute-du-Diable; final closure of the dam was being made in November and it was expected that the first unit would be in operation in late December. This station, which will contain five units each of 55,000 h.p., will tie-in to the present double-circuit transmission line running from Isle Maligne to Dolbeau.

The Manicouagan Power Company, which commenced construction in the early spring of 1951 of a development near the mouth of the Manicouagan River, comprising initially two generating units each of 45,000 h.p. under 125 ft. head, made such good progress that it was expected the first unit would come into production in December 1952, and the second unit early in 1953. To allow the building of the dam and headworks in the dry, the Manicouagan River, the third largest in the Province of Quebec, was successfully diverted through a tunnel in the river bank. The plant, with an ultimate capacity of 270,000 h.p., will provide reserve power for the pulp-and-paper industry at Baie Comeau and for community requirements; it also will supply electricity for secondary industries which are growing up, or expected to grow up, on the North Shore of the St. Lawrence River. In this connection, however, special negotiations are now being carried on with the Quebec Hydro-Electric Commission for the transmission of power via submarine cable to the South Shore of the St. Lawrence River, principally in order to supply the new Noranda (Gaspé) Copper Development. Although Quebec Hydro has announced plans for the Bersimis River, these plans do not call for production until 1956; since the Gaspé copper development's progress is conditioned upon the availability of power, the completion of the Manicouagan Power Project will allow the necessary power to be placed at the disposal of the new Gaspé copper project four to five years in advance of any other plans.

The Shawinigan Water and Power Company has not added any further generating capacity to its system. The work required for the diversion of run-off from 260 square miles of the drainage basins of the Upper Megiscane and Susie Rivers into the St. Maurice basin is well advanced, and this diversion will be in operation some time in 1953. The company has completed the work of raising the voltage of its lines from Isle Maligne to Quebec from 187 kV to 230 kV. A new 110 kV line from Sorel to Varennes has been virtually completed.

Price Brothers and Company has had under construction since June 1951 two hydro-electric developments on the Shipshaw River; construction is progressing on schedule, and the plants are expected to be in operation by the end of 1953. The main plant at Chute-des-Georges will have a capacity of 70,000 h.p. in two units under 348 ft. head, while the second at Chute-aux-Galets will have one unit of 9,000 h.p.

The Ste. Marguerite Power Company is proceeding on schedule with the construction of their hydro-electric power development on the Ste. Marguerite River at "61 Falls," seven miles above the mouth of the St. Marguerite River. The plant will have two

Fig. 6. One of five access shafts to the new 5½ mile pressure tunnel serving the Sir Adam Beck No. 2 station at Niagara Falls

Fig. 7. Excavation in progress for Sir Adam Beck No. 2 station, Niagara Falls

units each of 8,500 h.p. at 98 ft. head and will probably be placed in service in May 1954. Power will be delivered to Seven Islands and to Clarke City.

The MacLaren Quebec Power Company began construction in May of a new storage reservoir at the outlet of Kiamika Lake, and it is expected that it will be completed in the fall of 1953, in time to impound the 1954 spring run-off. The capacity of the reservoir will be 332,000 acre-feet of water, which will serve to provide a more constant flow on the Lievre River for the generating stations at High Falls and Masson.

The Quebec Streams Commission successfully maintained regulation of flow for power production and flood control on controlled rivers of the Province of Quebec through its extensive system of storage reservoirs. Preliminary studies of prospective water-power developments were carried out on the Lievre River at Mont. St. Michel, on the Pikauba River in Lake Kenogami watershed, on the Rupert and Broadback Rivers in James Bay watershed, on the Puyjalon and Mecatina Rivers on the St. Lawrence North Shore. Favourable progress was made on the reconstruction of Dam C, at the outlet of Lake Chateauvert. Flood protection works were carried out on a number of rivers throughout the province.

New Brunswick

Installed capacity in the province was slightly increased by the replacement of a 2,400 h.p. unit by one of 5,000 h.p. in the plant of the Maine and New Brunswick Electrical Power Company Limited on the Aroostook River.

The New Brunswick Electric Power Commission made good progress on its Tobique River Development of 27,000 h.p. in two units under 75 ft. head, and it is anticipated that the plant will be completed in March 1953. The Commission is actively concerned with current investigations of the water-power sites on the lower Saint John River, in conjunction with the international studies of storage possibilities which are being made in the headwater areas. The Commission's 69 kV transmission line from Tobique River to Woodstock is nearing completion, and 250 miles of rural distribution line were built.

Nova Scotia

The Nova Scotia Power Commission completed in November its Gulch development on the Bear River, consisting of one unit of 8,600 h.p. under 225 ft. head. Investigations and studies are now being made by the Commission covering a development of 5,000 h.p. on the Mersey River at Lower Great Brook. The main transmission lines of the Commission were extended by 99 miles of 69 kV line, and 28 miles are under construction; 125 miles of rural distribution line also were built.

The Nova Scotia Light and Power Company Limited brought into operation in September its 4,000 h.p. plant of one unit at 58 ft. head at White Rock on the Gaspereau River; this new station replaces an older plant of 1,105 h.p. so that the increase in capacity is 2,895 h.p. The company has under construction for 1953 operation a development on the Nictau River of one unit of 9,000 h.p. under 400 ft. head. The company built 20 miles of 69 kV line and six miles of 22 kV line, with 18 miles of 22 kV line under construction; 200 miles of rural line also were completed.

Newfoundland

The Newfoundland Light and Power Co. Ltd. expected to bring into operation in December its new

plant of 7,500 h.p. in one unit under 176 ft. head, at tidewater on the Horse Chops River, Cape Broyle. About four miles farther upstream, the Company also was constructing for 1953 operation a second plant which will have a capacity of 10,000 h.p. under 199 ft. head. Investigations are being made towards a new development of about 20,000 h.p. on Piper's Hole River at the head of Placentia Bay.

The Anglo-Newfoundland Development Company Limited proceeded with the modernisation of its two plants on the Exploits River. At Grand Falls, four 4,400 h.p. turbines were replaced by 5,500 h.p. units for an increase in capacity of 4,400 h.p. At a later date, an additional four units each of 1,700 h.p. will be replaced by units of 2,700 h.p. At its Bishop Falls plants, the replacement of two 1,700 h.p. turbines by units of 2,700 h.p. is expected to be completed early in 1953, and the remaining four units of this type will be changed over at some future date.

The Union Electric Light and Power Company is planning the building of two plants, one on Georges Brook of 1,200 h.p., and one on the Trinity River at Lockston of 4,000 h.p.; these sites are both located in Trinity North near Fort Rexton.

In Labrador, the Iron Ore Company proceeded with a development at Menihek Rapids on the Ashuanipi River, although transportation was largely by aeroplane. The plant will have an initial installation of 12,000 h.p. in two units under 34 ft. head and an ultimate installation of 24,000 h.p. It is anticipated that early in 1954 electrical energy will be supplied to the mining operations in the Burnt Creek and Knob Lake areas.

The above review covers in brief outline the hydro-electric undertakings which recently have been completed, are in the course of construction, or are more or less definitely planned. There are in addition other large projects, in various parts of Canada, which have been under investigation and which probably will be undertaken in the near future. Although a large number of the more attractive sites within convenient distance of present centres of population already have been developed, there is every prospect that further development of Canada's great water-power resources will be continued, and that for some time to come the basic power demands of the country's expanding economy will be supplied in large measure from hydraulic sources.

Flood Control Gate

The converging needle valve provided with a jet disperser affords an excellent means of controlling floods by the low-level discharge of water impounded by dams, but there are practical limits as to the size to which they can be made, and where very large volumes of water have to be bypassed there is perhaps no effective alternative to large sluice gates. Radial gates have much to commend them for this service but they are unsuitable for very large openings, and direct lift gates, which have no limitations, are therefore more often adopted. Whatever type of valve or gate is used, however, severe wear and tear from high-velocity flow and from turbulence are to be expected if the stream is disturbed. If the water carries sand, gravel or other abrasive debris the destructive action is greatly increased and may quickly impair and eventually destroy the important sealing faces of the regulating equipment. It is important, therefore, that the culvert control gear be designed to have a reasonable length of service, and to this end Glenfield & Kennedy Limited have developed a new type of gate.

This design, which has been provisionally protected, combines the desirable hydraulic flow conditions of the converging needle valve with the economic construction of the sluice gate, and is calculated to ensure efficient and reliable operation throughout many years of service with minimum attention. It is essentially a counterbalanced free-roller type of direct-lift sluice gate, the sealing or joint faces and roller trains of which are set clear of the stream flow and are not therefore subjected to any wear or tear whatsoever. This arrangement enables the sealing faces to be flexible, thus obtaining the maximum degree of water-tightness when the gate is closed. By the elimination of protruding grooves which would cause turbulence during operation, and the provision of a converging

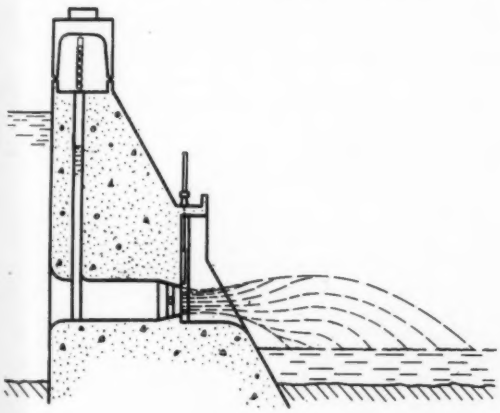


Fig. 1. Gate arrangement with circular culvert

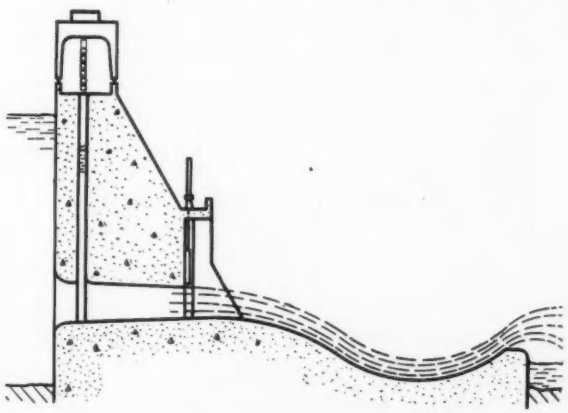


Fig. 2. Gate arrangement with rectangular culvert

outlet piece, an undisturbed stream flow throughout the culvert and a high discharge coefficient are achieved.

The gate can be raised and lowered under full upstream head and free-discharge conditions either manually or electrically. If power operation is employed, control can be either local or remote with gate-position indicators at the control points.

When the design is applied to a circular culvert a jet disperser can be installed in the waterway upstream of the gate. In square or rectangular channels this form of dispersion cannot be utilised but dissipation can be obtained by the provision of a downstream bucket, with or without a baffle arrangement, or a stillage pool.

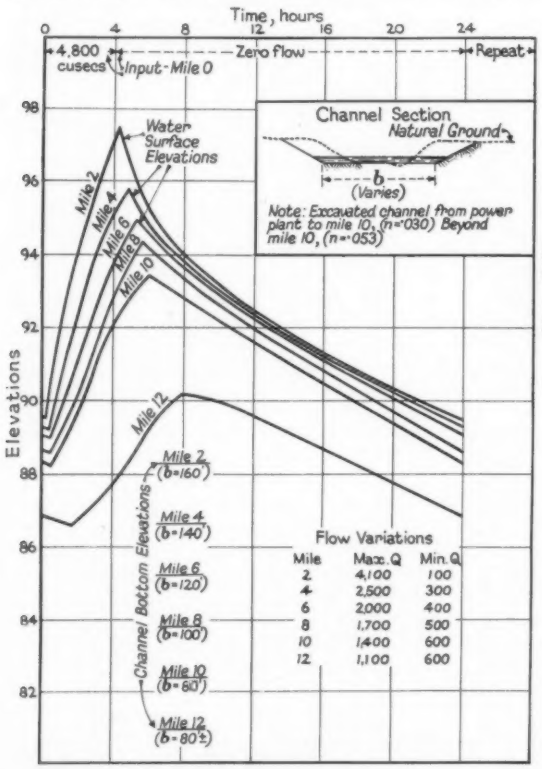
The accompanying diagrams show the gate applied to a typical gravity type dam having a circular culvert, Fig. 1, and to a dam with a rectangular culvert, Fig. 2. In the first instance the control equipment comprises a dewatering and emergency portable free-rolling gate at the inlet and a converging outlet piece in which are installed a jet disperser and the new type of control gate. In the second case the equipment is essentially the same excepting that the jet disperser has been replaced by a dispersion bucket.

Abstracts from the World Technical Press

Analog Circuit Solves Open-Channel Problem

A description is given of the method applied for solving a problem which faced the Area Planning Office of the USBR in Austin, Texas, in connection with one of its proposed projects. A proposed storage dam, many miles upstream from the diversion point of irrigation waters, seemed a likely place for a small hydro-electric power plant. A low dam, and narrow channel width below, meant a high tailwater level in periods of increased flows; this dictated a small plant with a maximum flow of about 1,500 cusec. and it was found that, at best, this plant would have only marginal economic feasibility. A full study of the area power requirements showed that peaking capacity with enough water to operate at a load factor as low as 16 per cent. could be integrated into the power system as dependable capacity. Consideration was given, therefore, to enlarging the narrow channel and thus lowering the tailwater level for larger plant capacity.

The obvious question then arose: how much excavation was justified, and, to determine this, how should the channel be designed? In computing the resulting backwater curves for tailwater elevation, what flows were to be expected at various points



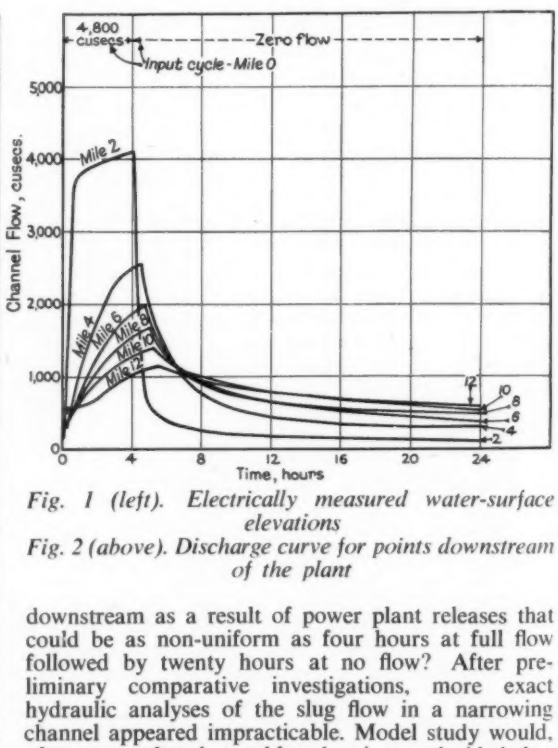


Fig. 1 (left). Electrically measured water-surface elevations

Fig. 2 (above). Discharge curve for points downstream of the plant

downstream as a result of power plant releases that could be as non-uniform as four hours at full flow followed by twenty hours at no flow? After preliminary comparative investigations, more exact hydraulic analyses of the slug flow in a narrowing channel appeared impracticable. Model study would, of course, solve the problem but it was decided that a quick electric analog check would be an inexpensive means of determining whether costlier model studies were justified.

The analog study was made in Denver research

laboratory of USBR and the plotted water surface elevations (Fig. 1), electrically measured, led to the conclusion that the channel improvement was feasible. Fig. 2 shows the discharge curves for points downstream, which indicate the ironing-out effect of time and distance on non-uniform flow in the non-uniform channel. (Karl O. Vartia, *Engineering News-Record*, Vol. 149, No. 23, Dec. 4, 1952, p. 44, 2 pp., 2 ff.)

Giacomo-Ponte Transmission Line

This new high-tension three-conductor line constitutes the Italian section of the international link connecting the Ponte plant of the Edison Group with

Fig. 1. Map of the Giacomo-Ponte transmission line

the Lucendro plant of the Swiss concern ATEL. Though built for a rated tension of 150 kV, the line will be operated at an average tension of 130 kV. The importance of this new link appears from the appended map, which shows that Lucendro is the junction point of the lines carrying the energy supplied by the Rodano, Aar, Maggia and Ticino plants and, in addition, connects at Amsted with the Mettlen-Reazzino line which cuts across almost the whole of Switzerland from north to south, linking up in the north with the French, German, Belgian and Dutch grids, and in the south with the Italian grid. The main characteristics of the S. Giacomo Pass—Ponte section are given in the schematic profile. The line and its installations, which are described in detail, was completed by the Edison Company on August 22, 1952. (*Quaderni di studi e notizie*, Vol. 8, No. 133, 16.10.1952, p. 650, 4 pp., 5 ff.)

Civil Engineering in French Hydro-Electric Development

The following figures give a very fair idea of the extent of civil engineering work carried out in connection with French development:—

Length of tunnels driven

1947	39,000 m.
1948	73,259 m.
1949	84,241 m.
1950	62,980 m.

Length of tunnels lined

1947	18,500 m.
1948	39,000 m.
1949	75,000 m.
1950	75,000 m.

Volume of earth work

1947	1,650,000 cu. m.
1948	2,500,000 cu. m.
1949	50,000 m.
1950	9,638,000 cu. m.

Volume of concrete and masonry

1947	526,000 cu. m.
1948	603,000 cu. m.
1949	1,055,000 cu. m.
1950	1,456,000 cu. m.

Installations put into service by the French Electricity Authority in 1950 increased the thermal power installed by 240,000 kW, and hydraulic production (average year) by 1,057 M kWh. The number of men employed on all working sites in 1949 varied between 38,500 and 45,900. (*L'Equipement Mécanique*, Vol. 31, No. 275, September 1952, p. 28.)

Developments in the Construction of Large Alternators

Considerations of general economy and easiness of operation have led, in the course of the last ten years or so, to the present pattern of power house with a few large turbines instead of a greater number of small- or medium-sized wheels. To keep in step with this trend, alternators have also been considerably increased in size and, to mention France only, 100,000 kVA or 137,500 kVA units, such as installed at Bort and Carline respectively, are now usual practice.

The evolution in the design and construction of these alternators is reviewed in detail in parallel with the development of hydro-electric units and the various types of turbine, special attention being devoted to turbo-alternators. Separate paragraphs deal with the

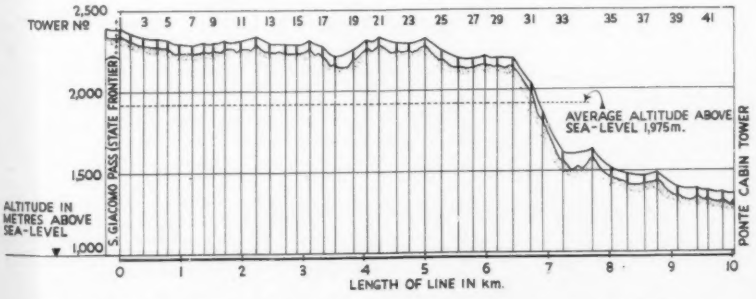

2,500
TOWER Nº
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41
2,000
1,500
1,000
ALTITUDE IN METRES ABOVE SEA-LEVEL
S. GIACOMO PASS (STATE FRONTIER)
AVERAGE ALTITUDE ABOVE SEA-LEVEL 1,975m.
PONTE CABIN TOWER
0 1 2 3 4 5 6 7 8 9 10
LENGTH OF LINE IN km.

Fig. 2. Schematic profile of the Giacomo-Ponte transmission line

cooling of alternators by hydrogen, and with their automatic control. (Pierre Devaux, *Electricité*, Vol. 36, No. 181, March 1952, p. 64, 7 pp., 9 ff.)

Underwater Rust Prevention

The following articles are included in an issue of the *Bulletin* of the Swiss Association of Electricians devoted to this important question:—

"Underwater corrosion tests with galvanized iron," by J. Friedli (p. 965, 9 pp., 7 ff.);

"Underwater rust prevention by spray coating," by H. Oertli, p. 973, 7 pp., 11 ff.; this article contains photographic illustrations of particular interest to the hydro-power engineer, such as sections of the trash-rack of the Mühleberg plant, in operation since 1920, and parts of a penstock of the Kandergrund plant;

"Results obtained with spray-coated sluice-gates," by F. W. Schweizer and G. Moll, p. 980, 2 pp., 3 ff.

"Results obtained with underwater rust preventives in the power plants of the Zurich Canton," by H. Wäger, p. 982, 2 pp., 2 ff.;

"Electro-plating as underwater rust preventive," by R. Gloor, showing illustrations of part of an intake trashrack 20 years in operation. P. 984, 2 pp., 2 ff.

"Measuring the thickness of zinc coatings by magnetic methods," by F. Buchmüller, p. 986/7, 1 f.;

"Testing the thickness and adhesiveness of sprayed rust-preventive zinc coating," by H. Oertli, p. 987, 4 pp., 4 ff. (*Bulletin de l'Association Suisse des Electriciens*, Vol. 43, No. 24, 29.11.1952.)

Water Hammer and Model Tests

The author refers to an article published in 1938 in No. 22 of the *Revue Générale de l'Hydraulique*, in which Professor Foch attempted to ascertain the laws of similitude to be applied to small-scale models used in water-hammer research, and sets forth the rule that water hammer can be investigated on models if the same scale is adopted for lengths as for time.

Professor Foch's results are then generalised and it is advocated that in some particular cases it may be possible to apply other rules of similitude. Among such cases the following are examined: reducing the thickness of the conduit in the model either in the same ratio as lengths and diameters, or in proportion to the square of the reduction scale of the lengths and diameters, or in proportion to the *n*th power of the said scale. (Jean Larras, *Revue Générale de l'Hydraulique*, Vol. 17, No. 66, November-December 1951, p. 283-284.)

Automatic Control of Grid Systems

The Bulletin of the French Association of Electrical Engineers devotes to this question the following articles, which fill almost the whole of its issue of last September:—

"Automatic reclosure on the French transmission network," by L. Roche, p. 501, 12 pp., 7 ff.;

"Results obtained in actual practice with automatic reclosing on the French 220 and 150 kV networks in 1950 and 1951," by M. Petard, p. 513, 3 pp.;

"Comparative stability study of the various types of reclosing systems in transmission and interconnection networks," by R. Robert, p. 516, 10 pp., 17 ff.;

"Automatic service resumption in an interconnection and transformer station," by R. Billon-Galland, p. 526, 7 pp., 3 ff.;

"Results obtained in tests with a B.B.C. quick-reclosing circuit breaker at the Clichy-sous-Bois station," by C. Couvreur, p. 533, 4 pp., 6 ff.;

"Results obtained in actual practice with a three-phase quick-reclosing circuit breaker in a 10 kV overhead line," by P. Ginouze, p. 537, 8 pp.;

"Report on quick reclosure tests carried out at La Négresse-Biarritz station in a 15 kV transmission system," by A. Loustau, p. 545, 3 pp.;

"Results obtained in actual practice with a quick-reclosing circuit-breaker," by J. Vadi, p. 548, 4 pp. (*Bulletin de la Société Francaise des Electriciens*, Series 7, Vol. 2, September 1952.)

Postwar Hydro-Electric Developments in N.E. Italy

The "Società Adriatica di Elettricità" (S.A.D.E.) has practically a monopoly of generation, transmission and distribution of electric energy in the North-Eastern Provinces of Italy. Most of this energy is produced in plants situated on the Piave, Adige and Cellina rivers.

The organisation of the S.A.D.E. is first reviewed with reference to the design and preliminary work in connection with the construction of hydro-electric plants. The types of dam adopted and the constructional methods applied are then discussed, especially in connection with large structures, and some of the typical plants built by S.A.D.E., such as the Lumiei, Piave di Cadore and Vall Gallina dams, and Ampezzo and Soverzene power houses, are briefly described. (Dr. Ing. Luciano di Brai, *Tecnica Italiana*, Vol. VII, No. 2, March-April 1952, p. 73, 10 pp., 12 ff.)

Lining the Bowland Tunnel. We regret that owing to a typographical error the qualifications of Mr. C. Parry, the consulting engineer for the design of the shutter, central mixing station, and concrete distributing and placing equipment, were incorrectly given. The correct version should be Mr. C. Parry, D.F.C., M.I.Struct.E.

CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

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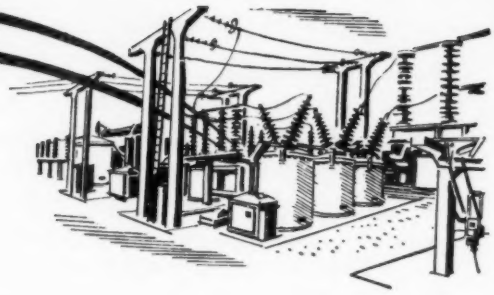

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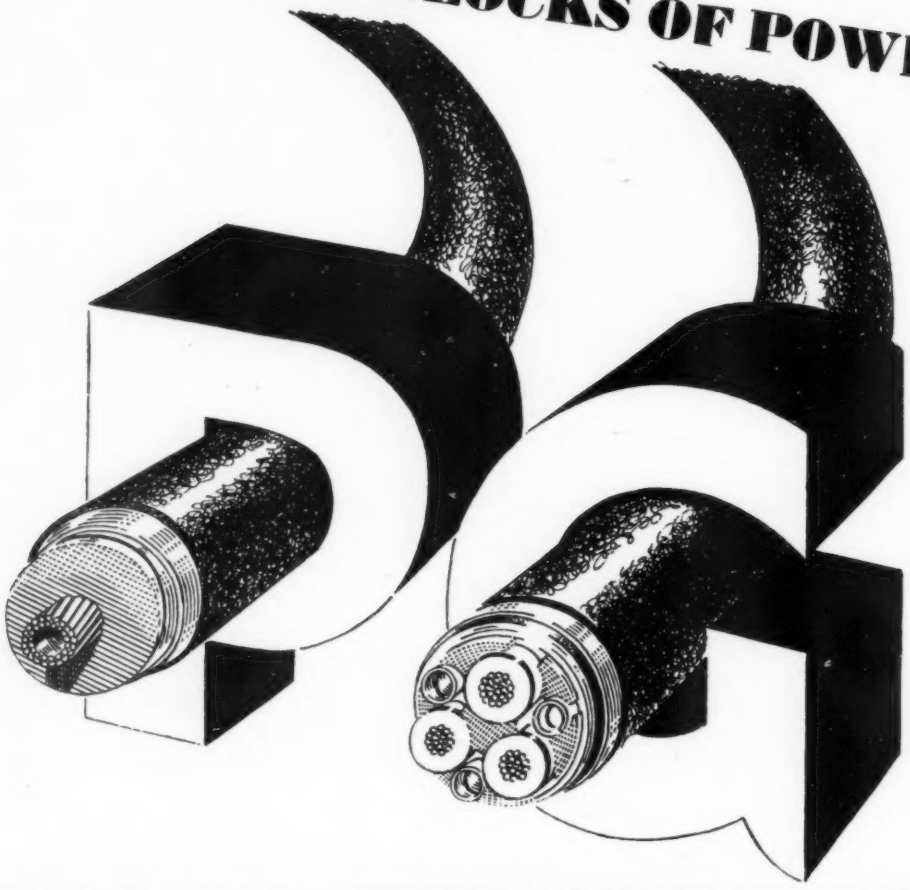

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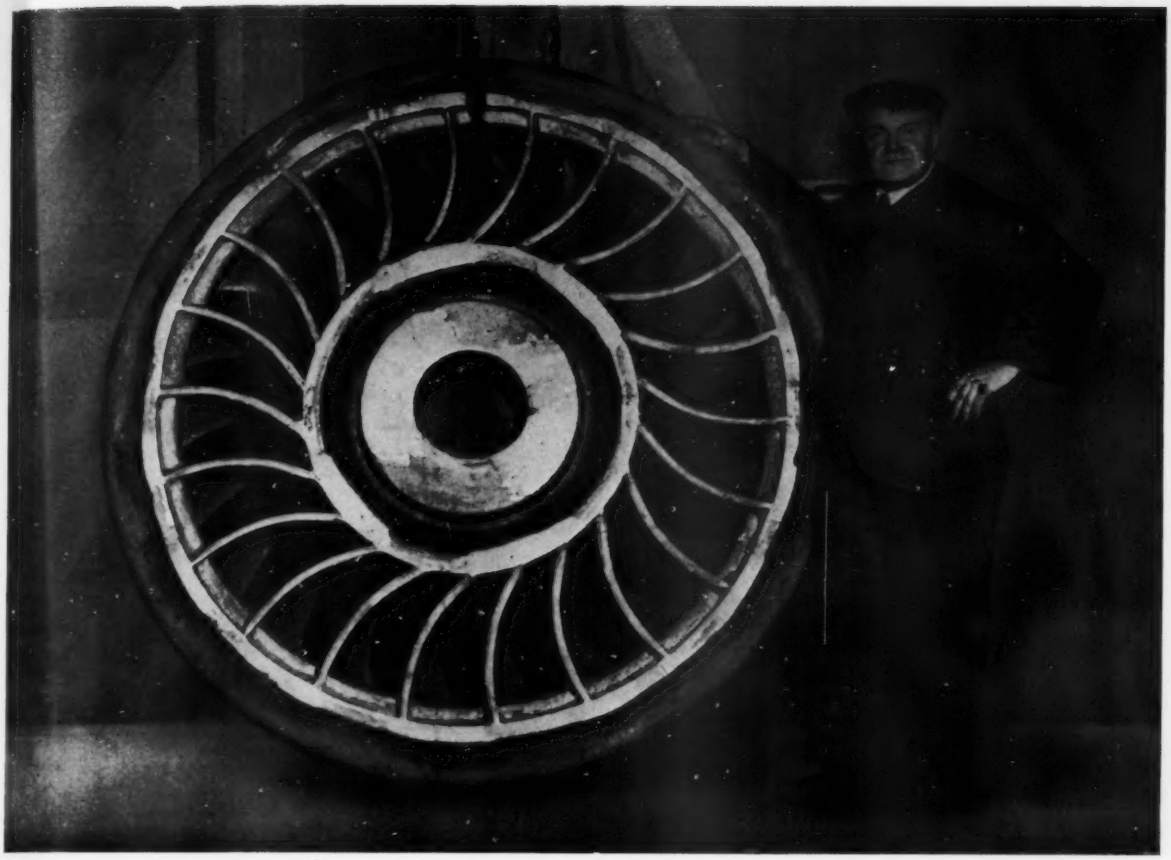

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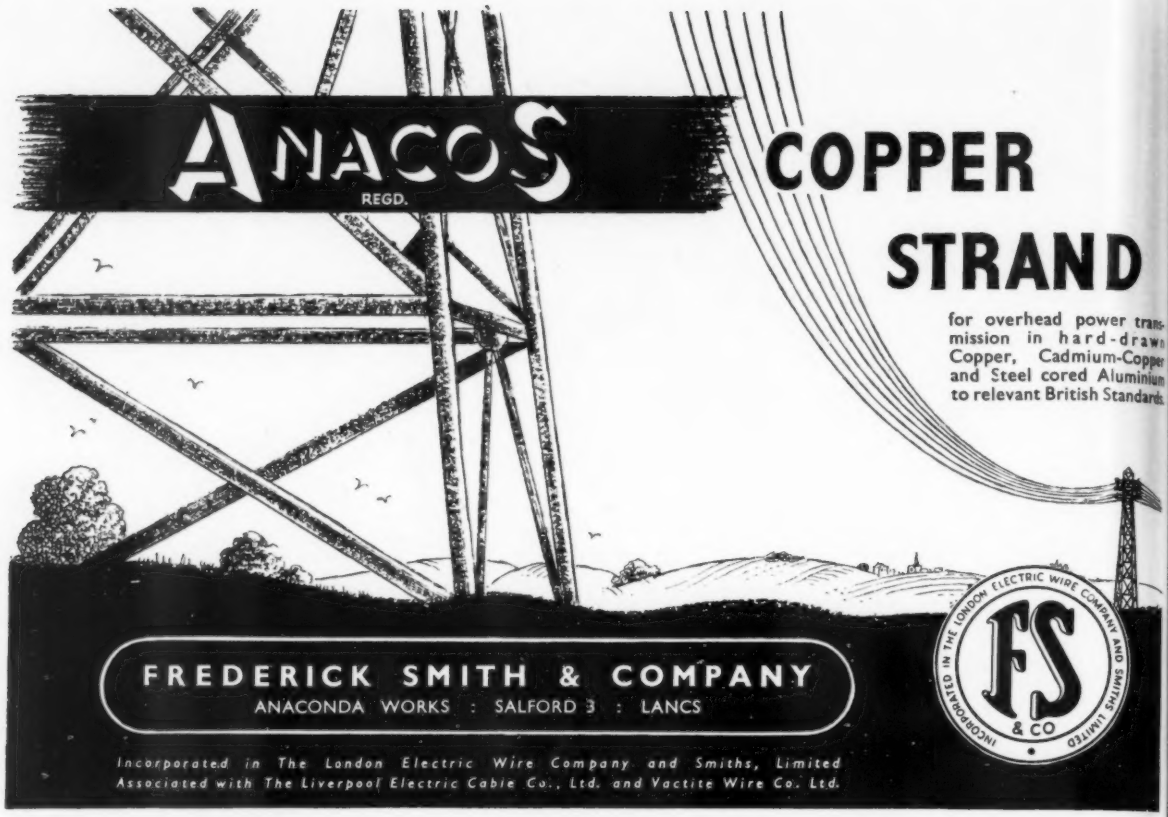
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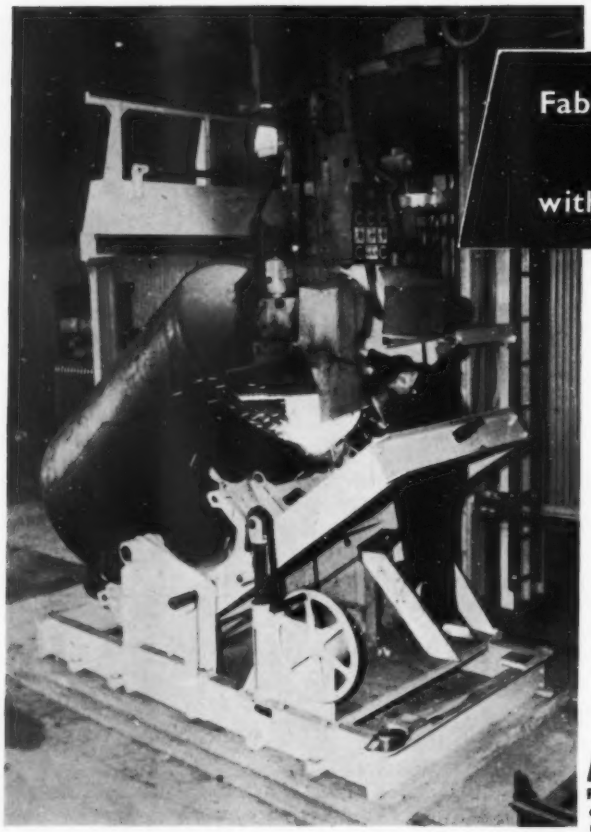

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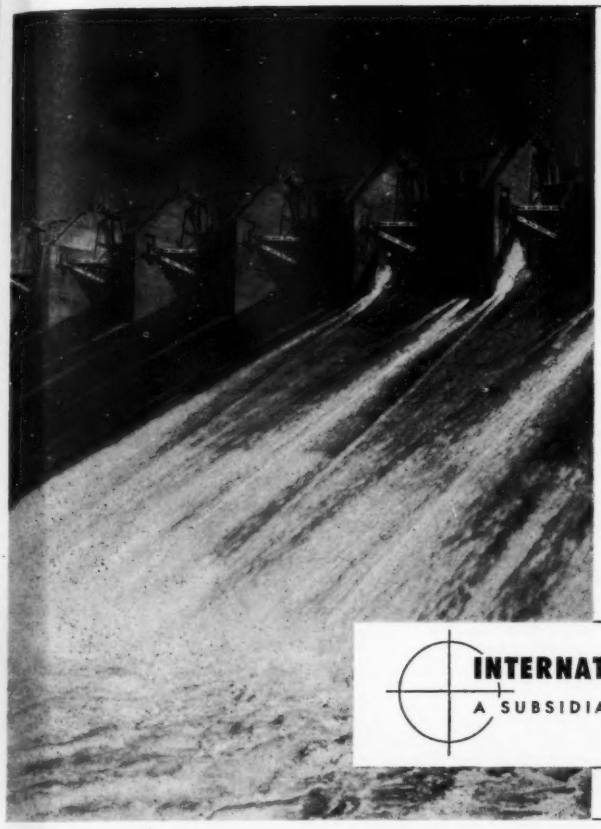

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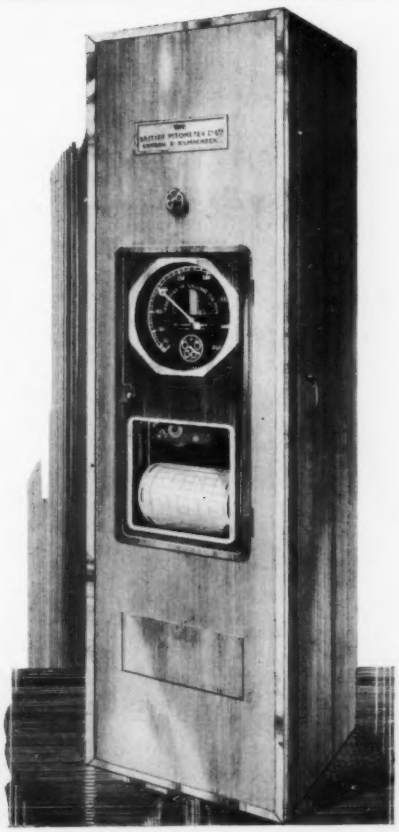

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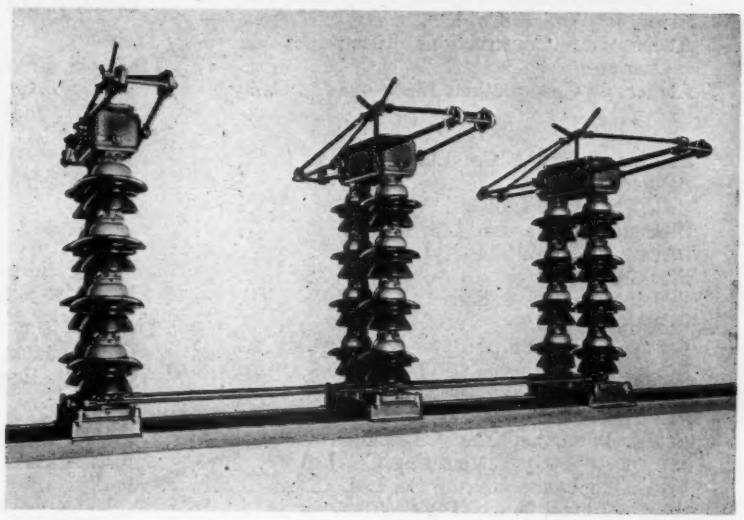

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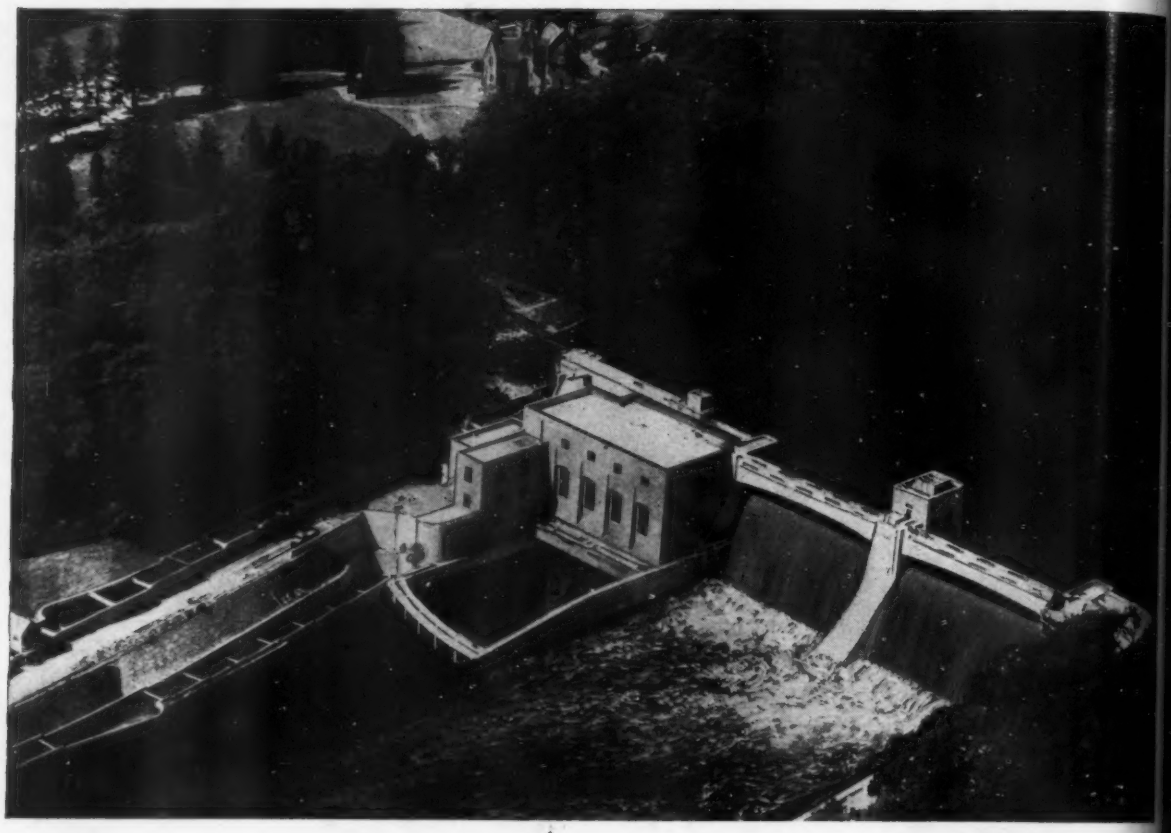

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